MANUAL OF ADMEASUREMENT.

THE

UNITED STATES

TONNAGE LAW OF 1864,

WITH AN ANALYSIS OF THE

Mode of Measuring Ships and Vessels,

ILLUSTRATED BY

FORMULÆ, DIAGRAMS, AND FULL DIRECTIONS FOR THE ADMEASUREMENT OF VESSELS OF ALL FORMS AND SIZES; WITH EXAMPLES OF ITS APPLICATION TO THE PURPOSES OF NAVAL ARCHITECTURE, AS WELL AS TO THE CUBATURE OF ALL BODIES OF WHATEVER CONFIGURATION, &C., &C.

BY I. R. BUTTS,

Author of the "United States Business Man's Law Cabinet"; "The Merchant's and Shipmaster's Manual and Shipbuilder's and Sailmaker's Assistant"; "Laws of the Sea"; &c. &c.

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1865.

RECOMMENDATIONS.

[*From the Hon. J. Z. Goodrich, Collector for the Port of Boston.*]

CUSTOM HOUSE, BOSTON.
Collector's Office, 12*th Dec.*, 1864.

Messrs. I. R. BUTTS & Co.

Gentlemen,—I have sent the copy of the Manual of Admeasurement, you handed me, to the Treasury Department. The work has been examined in this Office, and is regarded as a useful adjunct in execution of the new system of Admeasurement. The introduction and demonstration are exceedingly valuable, the latter making the reason of the rule clear, so that once understood it can never be forgotten, or incorrectly applied.

Yours resp'y,

J. Z. GOODRICH.

[*From the Hon. G. V. Fox, Assistant Secretary of Navy.*]

WASHINGTON, *Dec.* 12, 1864.

I. R. BUTTS & Co.,

Dear Sirs,—I thank you for the little book on Tonnage. It seems to be very accurate, and is necessary to enable our people to avail themselves readily of the new law.

Very faithfully,

G. V. FOX.

[*From Sam'l H. Pook, Naval Architect.*]

FAIR HAVEN, *Dec.* 13, 1864.

Messrs. I. R. BUTTS & Co.

Dear Sirs,—Your favor enclosing copy of Tonnage Law was duly received, for which I am much obliged.

It seems to be a work which will be much needed by all Nautical men, Ship-owners, and Ship-builders.

With respect, your obed't Servant,

SAM'L H. POOK.

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DEMONSTRATION

OF THE

RULE FOR MEASURING AREAS.

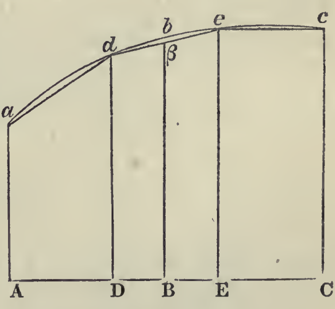
The formula commonly used in Shipbuilding, to express an area bounded by a straight line and a curved line, is as follows:—

$$\text{Area} = \left\{ A + 4P + 2Q \right) \frac{r}{3},$$

where A = Sum of first and last ordinates.
P = Sum of even ordinates.
Q = Sum of odd ordinates.
r = Common distance between ordinates.

The whole number of *ordinates* being *odd*, and the number of intervals being *even.*

The most simple demonstration, perhaps, is the following, given by M. Poncelet in his "Mécanique Industrielle."



Let A*abc*C be a portion of the area included between the curve *abc*, the line AC consisting of *two* of the *common* intervals r and the ordinates A*a*, C*c*: there being one intermediate ordinate B*b*.

Divide AC into 3 equal portions in D and E. So that

$$AD = DE = EC = \tfrac{1}{3}(AC) = \tfrac{1}{3}(2r) = \frac{2r}{3}.$$

At D and E erect ordinates D*d*, E*e*. Draw the chords *ad*, *de*, and *ec*; let *de* cut B*b* in β.

Then evidently, if the points $a, b, c,$ be taken sufficiently near, the area *abc*CA will be very approximately represented by the sum of the three trapezia A*d*, D*e*, and

E*c*, the difference being the three spaces included between the curve *abc*, and the chords *ad*, *de*, and *ec*, which are of no appreciable magnitude compared with the whole area. Now the area of a trapezium having two sides parallel $= \frac{1}{2}$ (the sum of the parallel sides) $\times$ perpendicular distance between them.

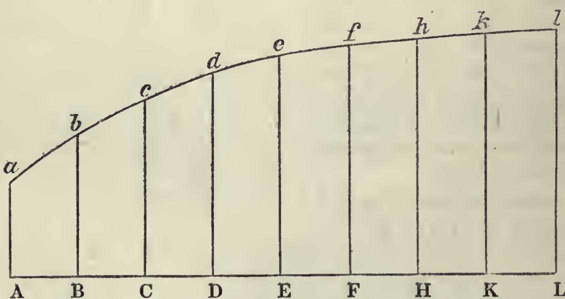
$$\therefore \text{Area trapezium } \mathrm{A}d = \tfrac{1}{2}(\mathrm{A}a + \mathrm{D}d)\ \mathrm{AD}.$$
$$\mathrm{D}e = \tfrac{1}{2}(\mathrm{D}d + \mathrm{E}e)\ \mathrm{DE}.$$
$$\mathrm{E}c = \tfrac{1}{2}(\mathrm{E}e + \mathrm{C}c)\ \mathrm{EC}.$$

$\therefore$ *Approximately* the area $\mathrm{A}abc\mathrm{C} = \frac{1}{2}\{\mathrm{A}a + 2\mathrm{D}d + 2\mathrm{E}e + \mathrm{C}c)\ \mathrm{AD}$

$$\because \mathrm{AD} = \mathrm{DE} = \mathrm{EC}.$$

Now $\mathrm{D}d + \mathrm{E}e = 2\mathrm{B}\beta$, as may be easily proved $\therefore 2\mathrm{D}d + 2\mathrm{E}e = 4\mathrm{B}\beta = 4\ \mathrm{B}b \because \mathrm{B}\beta$ differs from B*b* only by $b\beta$, which is of inappreciable magnitude compared with B*b*: hence calling A*a*, B*b*, C*c*, a_1, a_2, and a_3 respectively, and putting for AD its value $\frac{1}{3}$ AC or $\frac{2r}{3}$ we have

$$\text{Area } \mathrm{A}abc\mathrm{C} = \tfrac{1}{2}\{a_1 + 4a_2 + a_3) \times \frac{2r}{3} = (a_1 + 4a_2 + a_3)\frac{r}{3}.$$



Let now the whole area whose magnitude is required be divided into any number of intervals similar to A*abc*C, *i. e.* into any *even* number of spaces, having therefore an *odd* number of ordinates; the common interval being *r*, as in the figure, and let the ordinates

A*a*, B*b*, C*c*, D*d*, &c., be $a_1, a_2, a_3, a_4, \ldots \ldots a_l$

$$\text{Then area } CceE = (a_3, + 4a_4, + a_5)\frac{r}{3}$$

$$\text{also } EehH = (a_5, + 4a_6, + a_7)\frac{r}{3}$$

&c. — &c.

Adding, we obtain

$$\text{whole area} = (a_1 + 4a_2 + 2a_3 + 4a_4 + 2a_5 + \& + a_l)\frac{r}{3},$$

$$= \left\{a_1 + a_l + 4(a_2 + a_4 + a_6 + \&) + 2(a_3 + a_5 + a_7 + \&)\right\}\frac{r}{3},$$

$$= (A + 4P + 2Q)\frac{r}{3}.$$

PRISMOIDAL FORMULA.

The following *Rules for Solid Mensuration*, from the "Franklin Journal," illustrate, by a very simple method, the Rule for Measuring Areas.

The leading rules of solid mensuration, laid down in the books, separate rules being given for each solid, are the following, every one of which may be superseded by the Prismoidal Formula.

To find the solidity of a Cube ; Parallelopipedon ; Prisms ; Cones ; Cylinders ; Pyramids ; Frustum of Cone ; Frustum of Pyramid ; Prismoid ; Wedge ; Sphere.

A number of other special rules are given for the solidity of spheroids, paraboloids, and other solids of revolution, their spindles and segments ; to many of which the prismoidal formula is applicable.

By the Special Rules of the Books.

To find the solidity of a Cone.

RULE.—Multiply the area of the base by the height, and one-third of the product will be the solidity.

Given.—A cone having a diameter at the base of 2, a mid diameter of 1, and a height of 6. Query: The *solidity ?*

$2 \times 2 \times .7854 = 3.1416$
6

3)18.8496

Solidity = 6.2832

By Prismoidal Formula.

The Prismoidal Formula is,—Add into one sum the areas of the two ends, and four times the middle section parallel to them ; then this sum multiplied by one-sixth of the height will give the solidity.

In the case of the cone opposite, the diameter of the base being 2, and of the mid section 1, we have, by the prismoidal formula,

Base, $2 \times 2 \times .7854 = 3.1416$
4 times
mid sec. $1 \times 1 \times .7854 \times 4 = 3.1416$
Top $= 0.$

1-6th ht. $= 1. \times 6\ 2832$
Solidity = 6.2832

To find the solidity of a Wedge.

RULE.—To the length of the edge, add twice the length of the back; multiply this sum by the height of the wedge, and then by the breadth of the back: one-sixth of the product will be the solidity.

Given.—A wedge; length of edge 60, back length = 20, back breadth = 10, height 100. Query: The *solidity?*

Length of edge, = 60
Twice back, 20 × 2 = 40

100
100

10000
10

6)100000

Solidity = 16666⅔

Wedge—Solidity by prismoidal formula.

Area of base,	20 × 10 =	200
4 times mid sec.	40 × 5 × 4 =	800
Top	=	0
		1000

1-6th ht. = 16⅔ × 1000 = 16666⅔
Solidity = 16666⅔

To find the solidity of a Sphere.

RULE.—Multiply the cube of the diameter by decimal .5236, the product will be the solidity.

Given.—A sphere of a diameter or axis in length = 12. Query: The *solidity?*

12 × 12 × 12 × .5236 = 904.7808 the solidity.

Solidity of the Sphere opposite.

Top = 0.
4 times mid sec.
12 × 12 × .7854 × 4 = 452.3904
Base 0.

452.3904

1-6th ht. = 2 × 452.3904 = 904.7808
Solidity = 904.7808

Solidity of a Hemisphere.

Take the same dimensions as in the sphere above, and we have—

2)904.78

Solidity of Hemisphere = 452.39

Solidity of a Hemisphere.

Diameter of mid section = 10.392
Diameter of base = 12.
Height or radius = 6.
Then by Prismoidal Formula—
Area of base = 113.097
4 times mid section
10.392 × 10.392 × .7854 × 4 = 339.272
Top = 0.

452.369

1-6th ht. = 1 × 452.369 = 452.369
Solidity = 452.369

The difference in the last decimals is owing to too few decimal places having been used in the computation.

For the present purpose, it may be sufficient to have shown, by actual figures, working out examples of the most unpromising cases, the applicability of this formula to compute the solidity of a *cone*, *wedge*, *sphere*, and a *hemisphere*.

INTRODUCTORY REMARKS

Explanatory of the new Law for the Measurement of Shipping.

This law is divided into *five sections*, each on a separate and distinct subject. The first designates the time at which the law is to be enforced. The *second* states the dimensions that are to be entered in the vessel's register, and designates the deck which is to be named the tonnage-deck. The *third* section states that 100 cubic feet of *internal* capacity shall be taken to be one ton; it describes the manner in which the internal measurements are to be made, and directs that the tonnage calculated as therein directed, is to be entered in the vessel's register. The *fourth* section gives the tariff of charges for making the measurement and calculating the tonnage. The *fifth* section repeals all Acts of Congress that are inconsistent with the Act in question.

The law provides that this rule of measurement shall be in force "on and after the first day of January, 1865," and that owners may have their vessels measured and registered under the new law at any time after the 6th of May, 1864—the date of its approval.

The law explains in the clearest possible terms that, in vessels having three or more decks *to the hull* the second deck from below is to be the tonnage-deck; in all other cases, the upper deck *of the hull* is to be the tonnage-deck. Steamboats may have several decks that are not decks to the hull.

The *second section* only states the dimensions that are to be recorded in the register for the identification of the vessel, and which are, in fact, the common dimensions in use, except that the breadth of the stem is excluded from the length of the vessel. Neither this measure of length, nor the other dimensions of extreme breadth or depth of hold, has any thing to do with the calculation of internal capacity.

The law states that the length in the third section is not that which is given in the second section.

Section third states how the internal length is to be measured, for the purpose of ascertaining the tonnage or internal capacity, and the division into classes, is only for the purpose of determining the number of cross sections into which the hold is to be divided for this purpose. The whole subject of this section is the simple measuration of the internal capacity of the vessel inside of the ceiling and under the tonnage-deck plank, without allowance for beams, knees, keelsons, hooks, or internal framing of any kind. The law states what measurements are to be taken to gauge the ship, and tells how the measurements are to be used to obtain the internal capacity. Ship-builders, who calculate the displacement of their vessels, understand this rule, which is of very easy application, and of great accuracy.

The third section is found to describe exactly how the internal length of the vessel under the deck plank is to be ascertained:—The length on the top of the tonnage-deck, from the inside of the planking at the stem to the inside of the planking at the stern is measured, and from that length is deducted whatever rake there may be in the stem or in the stern, in the thickness of the deck plank, (the thickness of the deck plank is, generally, only three or four inches.)

The Act proceeds to state, that at each division of the length of the vessel, as determined in the third section, the depth is to be measured from a point at a distance of one-third of the round of the beam below the lower side of the deck to the limber-strake; the average thickness is named, so that the depth may not be reduced by extraordinary thickness being given to the limber-strake alone.

This *one-third of the round of the beam* is simply this:—An internal area is being measured, and one-third the spring of the beam is very nearly the mean height, and the area under the horizontal line at that mean height, will be almost identical with the actual area, embracing the whole spring of the beam.

It is at this mean height that the length of the vessel is measured.

At the stem, there is no round of the beam to be deducted; but when the vessel has a square stern, there is a round to the extreme after-end of the deck; and it was for that round, when the length was being measured, that it was directed to *deduct the rake of the stern timber in one-third of the round of the beam:* in a vessel with a round stern, no such deduction is to be made.

This rule of measurement for vessels is similar to that of the British law, and there has been no difficulty experienced there in finding persons to understand and apply it.

The old tonnage law made no exception for steam vessels, and there is no reason why there should be any in the present one. Steamers now have so many advantages over sailing vessels, that they are rapidly superseding them, and there is no necessity or good reason for further increasing these advantages.

AN ACT

TO

Regulate the Admeasurement of Tonnage of Ships and Vessels of the United States.

VESSELS WHEN TO BE MEASURED AND REMEASURED.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That every ship or vessel built within the United States, or that may be owned by a citizen or citizens thereof, on or after the first day of January, eighteen hundred and sixty-five, shall be measured and registered in the manner hereinafter provided; also every ship or vessel that is now owned by a citizen or citizens of the United States, shall be remeasured and reregistered upon her arrival after said day at a port of entry in the United States, and prior to her departure therefrom, in the same manner as hereinafter described: *Provided*, That any ship or vessel built within the United States, after the passage of this act, may be measured and registered in the manner herein provided.

REGISTER OF VESSEL, WHAT SHALL EXPRESS.

SEC. 2. *And be it further enacted*, That the *register* of every vessel shall express her *length* and *breadth*, together with her *depth*, and the *height under the third or spar deck*, which shall be ascertained in the following manner: — The tonnage-deck, in vessels having three or more decks to the hull, shall be the second deck from below; in all other cases the upper-deck of the hull is to be the tonnage-deck. The length from the forepart of the outer planking, on the side of the stem, to the after part of the main stern-post of screw steamers, and to the after part of the rudder-post of all other vessels measured on the top of the tonnage-deck, shall be accounted the vessel's length. The breadth of the broadest part on the outside of the vessel shall be accounted the vessel's breadth of beam. A measure from the under side of tonnage-deck plank, amidships, to the ceiling of the hold (average thickness) shall be accounted the depth of hold. If the vessel has a third deck, then the height from the top of the tonnage-deck plank to the under side of the upper-deck plank shall be accounted as the height under the spar-deck. All measurement to be taken in feet and fractions of feet; and all fractions of feet shall be expressed in decimals.

Tonnage of Vessel derived from Cubic Content.

Sec. 3. *And be it further enacted*, That the register tonnage of a vessel shall be her entire internal cubical capacity in tons of one hundred cubic feet each, to be ascertained as follows:

Length how taken and Number of Divisions.

Lengths.—Measure the length of the vessel in a straight line along the upper side of the tonnage-deck, from the inside of the inner plank, (average thickness,) at the side of the stem to the inside of the plank on the stern timbers, (average thickness,) deducting from this length what is due to the rake of the bow in the thickness of the deck, and what is due to the rake of the stern-timber in the thickness of the deck, and also what is due to the rake of the stern-timber in one-third of the round of the beam; divide the length so taken into the number of equal parts required by the following table, according to the class in such table to which the vessel belongs:

Table of Classes.

Class 1. Vessels of which the tonnage length according to the above measurement is fifty feet or under, into six equal parts.

Class 2. Vessels of which the tonnage length according to the above measurement is above fifty feet, and not exceeding one hundred feet long, into eight equal parts.

Class 3. Vessels of which the tonnage length according to the above measurement is above one hundred feet long, and not exceeding one hundred and fifty long, into ten equal parts.

Class 4. Vessels of which the tonnage length according to the above measurement is above one hundred and fifty feet, and not exceeding two hundred feet long, into twelve equal parts.

Class 5. Vessels of which the tonnage length according to the above measurement is above two hundred feet, and not exceeding two hundred and fifty feet long, into fourteen equal parts.

Class 6. Vessels of which the tonnage length according to the above measurement is above two hundred and fifty feet long, into sixteen equal parts.

Method of finding the Areas.

Transverse Areas.—Then, the hold being sufficiently cleared to admit of the required depths and breadths being properly taken, find the transverse area of such vessel at each point of division of the length as follows:—Measure the depth at each point of division from a point at a distance of one-third of the round of the beam below such deck, or, in case of a break, below a line stretched in continuation thereof, to the upper side of the floor-timber, at the inside of the limber-strake, after deducting the average thickness of the ceiling, which is between the bilge-planks and limber-strake; then, if the depth at the midship division of the length do not exceed sixteen feet, divide each depth into four equal parts; then measure the inside horizontal breadth, at each of the three points of division, and also at the upper and lower points of the depth, extending each measurement to the average thickness of that part of the ceiling which is between the points of measurement; number these breadths from above, (numbering the upper breadth one, and so on down to the lowest breadth;) multiply the second and fourth by four, and the third by two; add these products together, and to the sum add the first breadth and the last, or fifth; multiply the quantity thus obtained by one-third of the common interval between the breadths, and the product shall be deemed the transverse area; but if the midship depth exceed sixteen feet, divide each depth into six equal parts, instead of four, and measure, as before directed, the horizontal breadths at the five points of division, and also at the upper and lower points of the depth; number them from above as before; multiply the second, fourth, and sixth by four, and the third and fifth by two; add these products together, and to the sum add the first breadth and the last, or seventh; multiply the quantities thus obtained by one-third of the common interval between the breadths, and the product shall be deemed the transverse area.

Method of ascertaining the Register Tonnage of Vessel.

Computation from Areas.—Having thus ascertained the transverse area at each point of division of the length of the vessel, as required above, proceed to ascertain the register tonnage of the vessel in the following manner:—Number the areas successively *one*, *two*, *three*, &c., number one being at the extreme limit of the length at the bow, and the last number at the extreme limit of the length at the stern; then whether the length be divided according to table, into six or sixteen parts, as in classes one and six, or any intermediate number, as in classes two, three, four, and five, multiply the second, and every even numbered area, by *four*, and the third and every odd numbered area (except the first and last) by *two*; add these products together, and to the sum add the first and last, if they yield anything; multiply the quantities thus obtained by one-third of the common interval between the areas, and the product will be the cubical contents of the space under the tonnage-deck; divide this product by one hundred, and the quotient, being the tonnage under the tonnage-deck, shall be deemed to be the register tonnage of the vessel, subject to the additions hereinafter mentioned.

Measurement of the Poop and other closed in Space.

If there be a break, a poop, or any other permanent, closed-in space on the upper decks, on the spar deck, available for cargo, or stores, or for the berthing or accommodation of passengers or crew, the tonnage of such space shall be ascertained as follows:—

Measure the internal mean length of such space in feet, and divide it into an even number of equal parts of which the distance asunder shall be most nearly equal to those into which the length of the tonnage-deck has been divided ; measure at the middle of its height the inside breadths, namely, one at each end and at each of the points of division, numbering them successively, one, two, three, &c. ; then to the sum of the end breadths add four times the sum of the even-numbered breadths and twice the sum of the odd-numbered breadths, except the first and last, and multiply the whole sum by one-third of the common interval between the breadths ; the product will give the mean horizontal area of such space ; then measure the mean height between the planks of the decks, and multiply by it the mean horizontal area ; divide the product by one hundred, and the quotient shall be deemed to be the tonnage of such space, and shall be added to the tonnage under the tonnage-decks, ascertained as aforesaid.

Measurement of the Third or Spar Deck.

If a vessel has a third deck, or spar-deck, the tonnage of the space between it and the tonnage-deck shall be ascertained as follows:—

Measure in feet the inside length of the space, at the middle of its height, from the plank at the side of the stem, to the plank on the timbers at the stern, and divide the length into the same number of equal parts into which the length of the tonnage-deck is divided ; measure (also at the middle of its height) the inside breadth of the space at each of the points of division, also the breadth of the stem and the breadth at the stern ; number them successively, one, two, three, &c., commencing at the stem ; multiply the second, and all other even numbered breadths, by four, and the third, and all the other odd numbered breadths, (except the first and last,) by two; to the sum of these products add the first and last breadths, multiply the whole sum by one-third of the common interval between the breadths, and the result will give, in superficial feet, the mean horizontal area of such space; measure the mean height between the plank of the two decks, and multiply by it the mean horizontal area, and the product will be the cubical contents of the space; divide this product by one hundred, and the quotient shall be deemed to be the tonnage of such space, and shall be added to the other tonnage of the vessel, ascertained as aforesaid. And if the vessel has more than three decks, the tonnage of each space between decks, above the tonnage-deck, shall be severally ascertained in the manner above described, and shall be added to the tonnage of the vessel, ascertained as aforesaid.

Tonnage of Open Vessels how ascertained.

In ascertaining the tonnage of open vessels the upper edge of the upper strake is to form the boundary line of measurement, and the depth shall be taken from an athwartship line, extending from upper edge of said strake at each division of the length.

Registered Tonnage to be Carved on the Main Beam.

The register of the vessel shall express the number of decks, the tonnage under the tonnage-deck, that of the between-decks, above the tonnage deck; also that of the poop or other enclosed spaces above the deck, each separately. In every registered United States ship or vessel the number denoting the total registered tonnage shall be deeply carved or otherwise permanently marked on her main beam, and shall be so continued;

and if it at any time cease to be so continued, such vessel shall no longer be recognized as a registered United States vessel.

Charge for Measuring and Certificate.

Sec. 4. *And be it further enacted*, That the charge for the measurement of tonnage and certifying the same shall not exceed the sum of one dollar and fifty cents for each transverse section under the tonnage-deck; and the sum of three dollars for measuring each between-decks above the tonnage-deck; and the sum of one dollar and fifty cents for each poop, or closed-in space available for cargo or stores, or for the berthing or accommodation of passengers, or officers and crew above the upper or spar-deck.

Act not to apply to Vessels not required to be Registered or Enrolled.

Sec. 5. *And be it further enacted*, That the provisions of this act shall not be deemed to apply to any vessel not required by law to be registered, or enrolled, or licensed, and all acts and parts of acts inconsistent with the provisions of this are hereby repealed.

Apppoved May 6, 1864.

SUPPLEMENT.

Act of Congress amendatory of the Act of 1864,
Approved, February 28, 1865.

Be it enacted, &c., That the act entitled "An act to regulate the admeasurement of tonnage of ships and vessels of the United States," approved May sixth, eighteen hundred and sixty-four, shall be so construed that no part of any ship or vessel shall be admeasured or registered for tonnage that is used for cabins or state-rooms, and constructed entirely above the first deck, which is not a deck to the hull.

ANALYSIS OF THE MODE

FOR THE

ADMEASUREMENT OF TONNAGE.

The following "MODE" for the Admeasurement of Vessels, with Examples of its application to the purposes of Naval Architecture, &c., have been taken from the "*Review of the Laws of Tonnage*," by G. Moorsom, London. — This MODE for Measuring Vessels was adopted by the British Government, by *Act* of Parliament, in 1854, which Act has been substantially copied into the "*Act to regulate the Admeasurement of Ships and Vessels of the United States*," Approved, May, 1864. The Formulæ in "Moorsom's Review," have been altered to conform to the Table of Classes in the United States Law.*

PLAN BASED ON INTERNAL CAPACITY.

The system, for the admeasurement of vessels when the hold is clear, consists of a series of internal measurements, which at the time of taking them, are simply arranged in a prepared formula, from which the true cubical contents, and thence the tonnage, are directly computed by an easy arithmetical process.

The plan is founded or based on the correct *internal capacity* of vessels. The first object, therefore, was to attain a practically correct cubature of this space. This is accomplished by means

---

* The United States Rule of Measurement for vessels is similar to that of the English law, the principal difference being that ours has a greater number of *areas* or *sections*; making it more accurate and nearer the true internal capacity of the vessel.

The following is the English Table of *areas* or *sections*: —

Vessels of which the tonnage length is

	50 ft. or under - - - - - -	into 4 equal parts.
above	50 ft. and not exceeding 120 ft.	into 6 equal parts.
above	120 ft. and not exceeding 180 ft.	into 8 equal parts.
above	180 ft. and not exceeding 225 ft.	into 10 equal parts.
above	225 ft. - - - - - - - - -	into 12 equal parts.

purely legitimate; and the number of cubic feet so arrived at is divided by 100 for the register tonnage.

From this brief definition of the plan it is obvious that the tonnage resulting from it must afford an immediate and just knowledge of the capacities or sizes of all vessels, whatever be their form.

The tonnage so ascertained is simply a *cubical tonnage* or true expression of the internal cubical capacity, in which every ton of tonnage represents 100 cubic feet of space. So that, if by this process one vessel measures 500 tons, for instance, and another measures 1000 tons, it is known to a certainty that the latter vessel has double the cubical capacity of the former; for, in each case, every ton of tonnage contains exactly 100 cubic feet of space.

Or, speaking generally of the size of these two vessels, we should say of the first, that she is a vessel of 500 tons cubical measurement, of 100 cubic feet to the ton; and of the second, that she is a vessel of 1000 tons cubical measurement, of 100 cubic feet to the ton: having thereby a clear knowledge not only of the *comparative* magnitudes of the two, but of the *real* cubical capacity of each.

External measurement, even when applied to ascertaining the weight of the actual cargo of vessels, is not an eligible standard for tonnage admeasurement, inasmuch as heavy or dead-weight cargoes are not the predominant cargoes of commerce.

And that, when applied to any other extent, it is totally inadmissible; inasmuch as it is, then, neither a measure of the weight of cargoes, nor of the internal capacity: while, at the same time, it is productive of various inequalities operating most unjustly to the advantage of iron built vessels; being an inducement, moreover, to the building of weak, thin-sided vessels.

While, on the contrary, *internal* measurement, being a measure of the internal capacity, identified with the prevailing cargoes of commerce, is a fair and eligible basis for all the purposes for which tonnage admeasurement is established, as well for vessels built of *iron* as those built of wood; having an equalizing effect with regard to wood and iron vessels, and being at the same time, unattended by any inequalities in its operation, except giving an advantage in cases of heavy cargoes carried by vessels of increased scantlings; which, being few in comparison, argue little in opposition to its general eligibility; more particularly when it is considered that this very disadvantage is, in itself, an encouragement to the building of strong, thick-sided vessels, the opposite of which is the tendency of *external* measurement.

RULE FOR DETERMINING THE REGISTER TONNAGE.

Outline of Mode.

In all vessels, except those having a spar or third deck, the upper deck is the tonnage-deck, that is, the deck from which the tonnage of the hold is computed; but in vessels having a spar or third deck, the middle deck is the tonnage-deck; and the tonnage of the spaces above the tonnage-deck is in each case computed separately.

The inside length of the vessel at the medium height of the tonnage-deck is divided into a given number of equal parts, according to the length of the vessel; at each of the points of division a perpendicular transverse area of the vessel is calculated, by means of a general process hereinafter described; and from these areas (by means of the same general process as the areas themselves are calculated) the cubical content under the deck is ascertained; this cubical content is then divided by 100, which gives the register tonnage under the deck.

This is an outline of the operation; from which it will be seen that, when only the general process of obtaining the areas is understood, the whole theory of the system is substantially known.

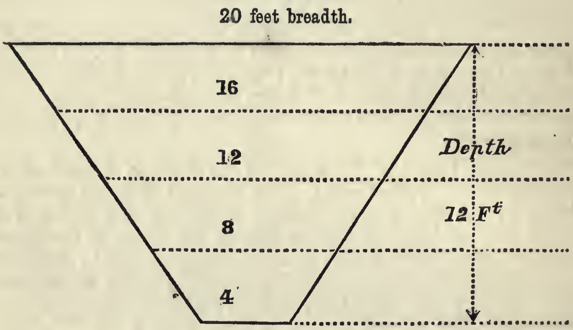
General Process for finding an Area, &c.

Art. 1.—*First, as to the means by which the areas are obtained:—*

The depth of the vessel is taken at the area to be measured, and being divided into a certain number of equal parts, the horizontal breadths (required to be always odd in their number) are measured at each point of division, also at the top and bottom of the depth; these breadths are then numbered in consecutive order, and placed accordingly in the general formula which follows. The even numbered breadths, as 2, 4, &c., are then multiplied by 4, and the odd numbered ones (except the first and last), as 3, 5, &c., are multiplied by 2; and the sum of these products, added to the first and last breadths, is then multiplied by one-third of the common interval between the breadths, which gives the area contained between the top and bottom breadths, as required.

Example of the Measurement of an Area.

Supposing the depth of the area to be twelve feet, and to be divided into four equal parts, the common interval between the breadths is three feet, so that one-third of the common interval is one foot; and supposing the breadths to be 4, 8, 12, 16 and 20 feet as shown in the figure below, the process is as follows:—



GENERAL FORMULA. Depth 12 ft. ÷ 4 = 3 ft. the com. int. betn. breadths.			
No.	Multi-pliers.	Breadths.	Products.
1	1	20	20
2	4	16	64
3	2	12	24
4	4	8	32
5	1	4	4

144
1 is ⅓ of com. int. betn. breadths.

144 area required.

In the same manner each area is obtained.

The Cubical Content under the Tonnage-deck.

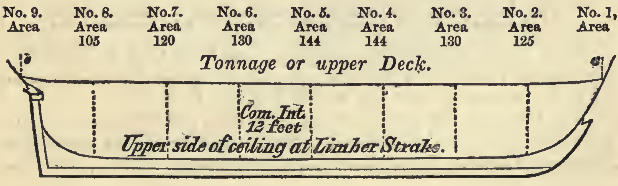
Art. 2.—*The cubical content under the tonnage-deck is obtained by means of the same general process, applied to the areas above found, as follows*:—

The areas are numbered in consecutive order, commencing at the bow, as shown in the figure annexed. The first area at the extreme limit of the bow is easily conceived, by inspection of the figure, to vanish into a line the breadth of the stem, and is therefore equal to 0; and the last area at the extreme limit of the stern vanishes, in a similar manner, into a line the breadth of the stern, and is therefore also equal to 0. But although these terminal areas are here equal to 0, they are, nevertheless, to act their parts in the formula just in the same manner as the terminal breadths do, in the case of the areas. This being understood, the process of obtaining the cubical contents from the areas is exactly the same as that of obtaining the areas from the breadths; that is to say (having numbered the areas in consecutive order, beginning at the bow), the even numbered ones, as 2, 4, &c., are multiplied by 4, and the odd numbered ones (except the first and last), as 3, 5, &c., are multiplied by 2; and the sum of these products, added to the first and last areas, is then multiplied by one-third of the common interval between the areas, which gives the cubical content required.

Example of computing the Cubical Content below the Tonnage-deck by means of the Transverse Areas.

Supposing the inside length of the vessel, at the tonnage or upper deck, as prescribed to be taken, to be 96 feet, it is divided into eight equal parts; this gives seven points of division or areas, in addition to the terminal ones at the extreme limits of the bow and stern, as seen by inspection of the figure below; and the common interval between the areas being 12 feet, one-third of the common interval is four feet.

And supposing the areas, found as in the foregoing example, to be as set forth at the points of division in the figure, the process is as follows:—



General Formula.

Length 96 ft. ÷ 8 = 12 ft. the com. int. betn. areas.

No.	Multi-pliers.	Areas.	Products.
1	1	0	0
2	4	125	500
3	2	130	260
4	4	144	576
5	2	144	288
6	4	130	520
7	2	120	240
8	4	105	420
9	1	0	0

2804
4 is ⅓ of 12 com. int. between the areas.

11216 cubic content under deck.

Hence we see the identity in the two operations, of finding the areas, and the cubical content under the deck from them; which, as already observed, constitutes the whole theory of the plan.

The cubical content having been thus found, it is to be divided by 100 for the register tonnage, that is,

Cub. Ft. Tons
11216 ÷ 100 = 112.16 register tonnage under the deck.

Correctness of Process proved by Examples.

Art. 3.—The general process having been thus delineated, it may be desirable next to show how far it can be depended upon, as to the correctness of the results derived from it.

For this purpose the following examples are introduced; first premising, that notwithstanding the simplicity of the operation, it is, nevertheless, founded on the purest mathematical principles.

The four following examples are selected as comprising within their limits the most extreme forms which merchant ships can possibly partake of, from the fullest flat-bottomed coaster to the sharpest wedge-like fruit-vessel; and as they are known regular figures of easy quadrature, namely, the *parallelogram*, *circle*, *parabola*, and *triangle*, they afford the means of geometrical comparison, by which the correctness of the Rule can be exactly estimated.

Example 1.

Parallelogrammical or Wall-sided Form.

Suppose the upper breadth, or breadth at tonnage-deck, to be 20 feet, and the depth 12 feet.

The depth being divided into four equal parts, the common interval between the breadths is three feet, so that one-third of the common interval is one foot. And the several breadths, from the nature of the figure, being equal to each other, the process is as follows:—

Measurement by Tonnage Rule.

General Formula.

Depth 12 ft. ÷ 4 = 3 ft. the com. int. betn. breadths.

No.	Multi pliers.	Breadths.	Products.
1	1	20	20
2	4	20	80
3	2	20	40
4	4	20	80
5	1	20	20

240
1 is ⅓ of 3, com. int. between breadths.

sq. ft. 240 area required.

Measurement by Geometry.

The area of a parallelogram = breadth × depth.

That is 20 × 12 = 240 square feet area required, which is the same as the result by tonnage rule.

Example 2.

Circular Form.

Suppose the upper breadth to be 20 feet, and the depth, in this case, to be 10 feet, so that the area may be a perfect semicircle.

The depth being divided into four equal parts, the common interval between the breadths is, in this case, 2.5 feet, so that one-third of the common interval is .833 feet. And the several breadths, measured from the figure, being as shown in the formula, the process is as follows;—

Measurement by Tonnage Rule.

General Formula.

Depth 10 ft. ÷ 4 = 2.5 ft. the com. int. betn. breadths.

No.	Multipliers.	Breadths.	Products.
1	1	20	20
2	4	19.5	78
3	2	17.5	35
4	4	13.5	54
5	1	0	0

Measurement by Geometry.

The area of a semicircle $= \dfrac{\overline{\text{rad}}|^2 \times 3.14159}{2}$:

That is, $\dfrac{\overline{10}|^2 \times 3.14159}{2} = 50 \times 3.14159 =$

157.079 square feet area required.

Note.—It is seen by these results that the tonnage measurement differs from the geometrical mensuration by 1.3 feet, or about three quarters per cent; which difference, however, would be found to vanish, in a practical sense, by the employment of a greater number of breadths.

```
     187
    .833 is ⅓ of 2.5 com. int. between breadths.
    ----
     561
    561
   1496
    ----
sq. ft. 155.771 area required.
```

Example 3.

Parabolic Form.

Suppose the upper breadth to be 20 feet, and the depth 12 feet.

Then the focus of the parabola from vertex is 3.6 feet. And the principal parameter is 14.4 feet, from which elements the figure is geometrically constructed.

The depth being divided into four equal parts, the common interval between the breadths is three feet, so that one-third of the common interval is one foot. And the several breadths, measured from the figure, being as shown in the formula, the process is as follows :—

Measurement by Tonnage Rule.

General Formula.

Depth 12 ft. ÷ 4 = 3 ft. the com. int. betn. breadths.

No.	Multipliers.	Breadths.	Products.
1	1	20	20
2	4	18.8	75.2
3	2	15.2	30.4
4	4	8.6	34.4
5	1	0	0

160
1 is $\frac{1}{3}$ of 3 com. int. between breadths.

sq. ft, 160 area required.

Measurement by Geometry.

The area of a parabola = 2-3d of the ordinate × abscissa.

That is, 2-3d of 20 × 12 = 160 square feet, area required, same as by tonnage rule.

Example 4.

Triangular or Wedge-like Form.

Suppose, again, the upper breadth to be 20 feet, and the depth 12 feet.

The depth being divided into four equal parts, the common interval between the breadths is three feet, so that one-third of the common interval is one foot.

And the several breadths, being as shown in the formula, the process is as follows :—

Measurement by TONNAGE RULE.

General Formula. Depth 12 ft. ÷ 4 = 3 ft. the com. int. betn. breadths.			
No.	Multipliers.	Breadths.	Products.
1	1	20	20
2	4	15	60
3	2	10	20
4	4	5	20
5	1	0	0

Measurement by Geometry.

The area of a triangle = ½ the base × perpendicular height.

That is ½ of 20 × 12 = 120 square feet, area required, same as by tonnage rule.

120
1 is ⅓ of 3, com. int. between breadths.

sq. ft. 120 area required.

Having thus shown that the process, when applied to the fullest and sharpest, as well as to the intermediate shapes of the circle and parabola, may be considered, in a practical sense, as being mathematically correct, it may be fairly inferred that its operations, in all other cases conceivable to lie between these extremes, will be attended with equally satisfactory results ; at the same time observing that the greater the irregularity of the curve, or in the deviations of the breadths, the greater should be the number (always an odd number) of breadths employed.

In the four preceding examples, the investigation of the measurement of areas only has been the question. But the process is equally valuable for ascertaining the cubature of solids. The rationale of its equal eligibility in the one case as in the other is easily conceived, as follows :—

A circumscribed area can be supposed to be completely covered by an infinite number of lines or breadths indefinitely near to each other; and as these breadths wholly make up the area, it is manifest that the sum of them must be the area itself. Now the integration of these breadths is exactly what the rule effects, by the employment, as already shown, of only a few of them.

In the same manner, if we conceive a solid body to be made up of an infinite number of sections or areas indefinitely near to each other, it is manifest that the sum of these areas or infinitesimal laminæ constitute the body itself.

As the process must equally accomplish the summation of the areas as it does that of the breadths, if we substitute the areas for the breadths, it must therefore be equally applicable to the cubature of solids as it is to the measurement of areas. (See page 65.)

Tonnage of the Spaces above Deck.

Art. 4.—The method of obtaining the tonnage under the tonnage deck, having now been, generally, described, the tonnage of the spaces above this deck, (videlicet the poop, forecastle, &c., and in ships having a third or spar-deck, the space between the spar and tonnage-decks,) being ascertained on the same principles, a practical example of each will be readily understood.

MEASUREMENT OF THE POOP.

The inside length of the poop, at the middle of its height, is first taken, and divided into two equal parts;* three breadths (also at the middle of its height) are then measured (numbered in the formula 1, 2, 3), the first at the fore end of the poop, the second at the middle point of its length, and the last at its after end; then to the first and last of these breadths add four times the middle one, and multiply the sum by one-third of the common interval between them, which gives a mean horizontal area of the poop; this, being multiplied by its height, gives its cubical content, which, divided by one hundred, gives the tonnage of the poop.

Example of Computation.

Suppose the inside length at the middle of the height to be sixty feet; this, being divided into two equal parts,* gives thirty feet for the common interval between the breadths, so that one-third of the common interval is ten feet.

Suppose, also, the height of the poop to be six feet, and the three breadths, measured as above directed, to be as set forth in the following formula, the process is then as follows:—

Note. * The United States Rule for measuring the Poop or any other permanent closed-in space on the upper deck, available for cargo, stores, &c., requires that it shall be divided into an even number of equal parts, of which the distance asunder shall be most nearly equal to those into which the length of the tonnage-deck has been divided. [See Law at page 19.]

GENERAL FORMULA.

Length 60 ft. ÷ 2 = 30 ft. the com. int. betn. breadths.*

No.	Multipliers.	Breadths.	Products.
1	1	20	20
2	4	19	76
3	1	18	18

114
10 is $\frac{1}{3}$ of 30, com. int. between breadths.
sq. ft. 1140 mean horizontal area of poop.
6 height.
Cubic content 6840 ÷ 100 = 68.4 tons, reg. ton. of poop.

It will be seen that the above formula is the same as that employed in the examples of finding the areas in the preceding Articles 1 and 3, with this difference, only, that fewer ordinates or breadths are here employed. If five or seven breadths are measured instead of three, then the odd numbered breadths (excluding the first and last) must be multiplied by two, as in those examples.

* *See Note on preceding page, and Law at page* 19, *for United States Rule for measuring the Poop or other closed-in Space on the upper deck.*

MEASUREMENT OF THE FORECASTLE.

The admeasurement of the forecastle is precisely the same as that for the poop, No. 1 at the fore end of the forecastle, being the breadth of the stem at that place, &c.

Example of Computation.

Suppose the inside length at the middle of its height to be thirty feet; this, being divided into two equal parts, gives fifteen feet for the common interval between the breadths, so that one-third of the common interval is five feet.

Suppose, also, the height of the forecastle to be six feet, and the three breadths, measured as above directed, to be as set forth in the following formula, the process is then as follows :—

GENERAL FORMULA.

Length 30 ft. ÷ 2 = 15 ft. the com. int. betn. breadths.

No.	Multipliers.	Breadths.	Products.
1	1	1.25	1.25
2	4	14.00	56.00
3	1	20.00	20.00

77.25
5 is ⅓ of 15, com. int. between breadths.

386.25 mean horizontal area of forecastle.
6 height of forecastle.

Cubic content 2317.50 ÷ 100 = 23.17 tons, register tonnage of forecastle.

SPAR AND TONNAGE-DECKS.

Measurement of the Space between the Spar and Tonnage-Decks in Vessels having a Spar or Third Deck.

Here, also, the process, except in the nature of the details, is identically the same as in all the preceding cases.

The inside length of this space, at the middle of its height, is first taken, and divided into the same number of equal parts as there are divisions of the length of the tonnage-deck; the inside breadths (also at the middle of its height), at each of the points of division, are then measured, also the breadth at the stern and the breadth of the stem; and numbering them successively 1, 2, 3, &c., (No. 1 being that of the stem), multiply the 2nd, 4th, 6th, &c., including all the even numbered breadths, by 4, and the 3rd, 5th, 7th, &c., including all the odd numbered breadths, except the first and last, by 2; to the sum of these products add the first and last breadths; this quantity multiplied by one-third of the common interval between the breadths gives a mean horizontal area of the space between decks; which, being multiplied by the height between the two decks, gives the cubical content; and this, divided by one hundred, gives the register tonnage of the space required.

Example of Computation.

Suppose the inside length at the middle of the height to be 96 feet; this, being divided into eight equal parts, gives twelve feet for the common interval between the breadths, so that one-third of the common interval is four feet.

Suppose, also, the height of the space to be seven feet, and the breadths measured as above directed, to be as set forth in the formula below, the process is then as follows:—

General Formula. Length 96 ft. ÷ 8 = 12 ft. the com. int. betn. breadths.			
No.	Multipliers.	Breadths.	Products.
1	1	1	1
2	4	22	88
3	2	24	48
4	4	25	100
5	2	26	52
6	4	25	100
7	2	24	48
8	4	23	92
9	1	22	22

551
4 is ⅓ of 12, com. int. between breadths.

2204 mean horizontal area of space.
7 height of space.

Cubic content 15428 ÷ 100 = 154.28 tons, register tonnage of space between spar and tonnage deck.

GENERAL DIRECTIONS FOR TAKING THE MEASUREMENTS OF VESSELS.

The *correctly* taking of the required measurements being of considerable importance, the following general directions to that end may be useful for the guidance of those who have not a professional acquaintance with the subject :—

Length.—The length at the tonnage-deck is to be taken by tightly stretching a line on the upper surface of the deck, at such a parallel distance from the middle line of the ship as to clear the several hatchways and other obstacles that may present themselves ; the line is then to be measured, marking the ends of the line on the deck ; these points are then to be squared in to the middle line of the ship, and the distances taken from them so squared in, to the inside of the plank at the bow and stern, deducting from this length what is due to the rake of the bow in the thickness of the deck, and what is due to the rake of the stern-timber in the thickness of the deck, and also what is due to the rake of the stern-timber in one-third of the round of the beam ;* the sum of these two distances added to the length of the line measured, as aforesaid, gives the whole length required.

Points of Division of the Length, or Stations of the Transverse Areas.—The length, taken as above described, being divided into the required number of equal parts, the points of division, which are the stations of the areas, are to be marked correctly on the tonnage-deck : a line is then to be extended down the main hatchway, at the middle line of the ship, in a direction perpendicular to the keel, by means of a square placed on the upper side of the keelson ; the distance of the midship area from this line at the tonnage-deck is then to be set off from this line on the keelson, which gives the station of the midship area on the keelson ; and the stations of the others are obtained on the keelson by setting off afore and abaft the midship one, the common interval between them, as already marked off on the tonnage-deck.

* This is to give the length at the medium height of deck.

FORMULA

For the use of the Measuring Surveyor, in the practical operation of the Admeasurement of the Register Tonnage of Merchant Shipping.

Length.—Taken inside on tonnage-deck, from inside of plank at stem, to inside of midship stern timber or plank there (as the case may be); the length so taken, allowing for rake at bow and stern in the thickness of deck and one-third of round of beam, to be divided into a number of equal parts (which determines the number and stations of the areas), according to the length, as follows:—

UNITED STATES TABLE OF CLASSES.

Vessels of which the tonnage length is

50 ft. or under - - - - - - into 6 equal parts.
above 50 ft. and not exceeding 100 ft. into 8 equal parts.
above 100 ft. and not exceeding 150 ft. into 10 equal parts.
above 150 ft. and not exceeding 200 ft. into 12 equal parts.
above 200 ft. and not exceeding 250 ft. into 14 equal parts.
above 250 ft. - - - - - - - - - into 16 equal parts.

Area No. 1 is at the extreme limit of the bow. Area No. 2 is at the 1st point of division; the rest are numbered in succession, the last Area being at the extreme limit of the stern.

Depths.—Taken at each point of division or area, from the under side of tonnage-deck to ceiling at inner edge of limber-strake, deducting therefrom one-third of the round-down of the beam; the depths, so taken, to be divided into four equal parts, if midship depth should not exceed sixteen feet, otherwise into six equal parts.

Breadths.—Taken at each point of division of the depths, and also at the upper and lower points of the depths. The upper breadth of each area is to be set down in its respective column, in a line with No. 1 (left hand numerals), and the rest in succession.

N. B. The number of columns for areas will vary according to the length, as in the classes above given, and will be equal to the number of parts into which the length is divided plus 1.

Vessel's Name—

Length taken as above, feet ÷ = feet, the common interval between the areas.

Depths divided into equal parts, the Midship Depth being than 16 feet.

		Area 1.		Area 2.		Area 3.		Area 4.		Area 5.		Area 6.		Area 7.		Area 8.		Area 9.	
Depths.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.	
Com int. between breadths.																			
No. of Bdths.	Multipliers.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.	Bdths.	Products.
1	1	Ft.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.		Ft.	
2	4																		
3	2																		
4	4																		
5	2																		
6	4																		
7	1																		
⅓ com. int btn. brdths.			0																0
			0																
		Area 1.		Area 2.		Area 3.		Area 4.		Area 5.		Area 6.		Area 7.		Area 8.		Area 9.	

Cubic Content and Register Tonnage.

No. of Areas.	Areas brought up. Sq. Ft	Multipliers.	Products.
1		1	
2		4	
3		2	
4		4	
5		2	
6		4	
7		2	
8		4	
9		1	

⅓ Cm. in. bet. areas.

÷ 100 = Cub. ft. Reg. Tons.

NOTE.—Add Poop.—See Formula page 34.

GENERAL FORMULA.

Length, 100 feet ÷ 8 = 12.5 feet, common interval between areas.

Depths divided into six equal Parts, the Midship Depth being *more* than 16 feet.

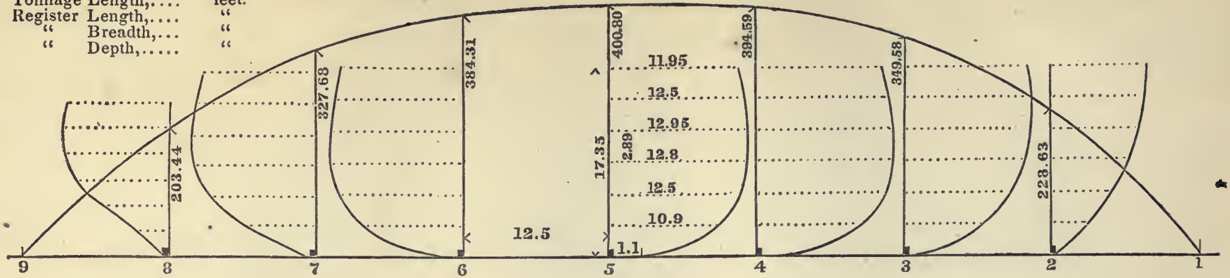
No. of Bdths.	Multi-pliers.	Area 1. Bdths.	Area 1. Pro-ducts.	Area 2. Bdths.	Area 2. Pro-ducts.	Area 3. Bdths.	Area 3. Pro-ducts.	Area 4. Bdths.	Area 4. Pro-ducts.	Area 5. Bdths.	Area 5. Pro-ducts.	Area 6. Bdths.	Area 6. Pro-ducts.	Area 7. Bdths.	Area 7. Pro-ducts.	Area 8. Bdths.	Area 8. Pro-ducts.	Area 9. Bdths.	Area 9. Pro-ducts.
Depths		Ft. —		Ft. 17.6		Ft. 17.5		Ft. 17.4		Ft. 17.35		Ft. 17.55		Ft. 17.0		Ft. 14.7		Ft. —	
Com int. between breadths.		—		2.93		2.916		2.9		2.89		2.925		2.83		2.45		—	
1	1	Ft.		Ft. 18.3	18.3	Ft. 23.2	23.2	Ft. 23.8	23.8	Ft. 23.9	23.9	Ft. 22.8	22.8	Ft. 21.6	21.6	Ft. 18.2	18.2	Ft.	Ft.
2	4	No	area.	17.6	70.4	23.9	95.6	24.9	99.6	25.0	100.0	24.0	96.0	22.8	91.2	19.0	76.0	No	area.
3	2	fore end.		16.3	32.6	23.9	47.8	25.6	51.2	25.9	51.8	24.8	49.6	23.5	47.0	19.2	38.4	after end.	
4	4			14.5	58.0	22.8	91.2	25.0	100.0	25.6	102.4	24.6	98.4	23.2	92.8	17.2	68.8		
5	2			11.6	23.2	20.2	40.4	24.0	48.0	25.0	50.0	23.6	47.2	20.5	41.0	12.0	24.0		
6	4			7.3	29.2	15.0	60.0	20.5	82.0	21.8	87.2	20.0	80.0	13.2	52.8	5.3	21.2		
7	1			1.6	1.6	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5	1.5		
⅓ Com. int. bet.			0		233.3		360.4		406.8		417.5		396.2		348.6		248.1		0
				brdths.	.98		.97		.97		.96		.97		.94		.82		
					18664		25228		28476		25050		27734		13944		4962		
					20997		32136		36612		37575		35658		31374		19848		
			0	sq ft	228.634		349.588		394.596		400.800		384.314		327.684		203.442		0
		Area 1.		Area 2.		Area 3.		Area 4.		Area 5.		Area 6.		Area 7.		Area 8.		Area 9.	

Cubic Content and Register Tonnage.

No. of Areas.	Areas brought up. Sq. Ft.	Multi-pliers.	Pro-ducts.
1	0	1	0
2	228.63	4	914.52
3	349.59	2	699.18
4	394.60	4	1578.40
5	400.80	2	801.60
6	384.31	4	1537.24
7	327.68	2	655.36
8	203.44	4	813.76
9	0	1	0
			7000.06
⅓ cm. in. bet. areas.			4.17
			4900042
			700006
			2800024
		cub. ft.	29190.2502
÷ 100 = 291.90 Reg. Tons.			

NOTE.—Add Poop.—See Formula page 34.

Tonnage Length,....		feet.
Register Length,....		"
"	Breadth,...	"
"	Depth,.....	"



The above DIAGRAM represents the curve of areas formed by ordinates in proportion to the areas of the corresponding sections ; and it will show if any errors have been made in the measurements or in the calculations.

Its construction is as follows : On the straight line are set off the exact position of the areas, according to the length of the vessel ; on these stations, marked 1, 2, 3, &c., are set off, at right angles from the straight line—on a scale of ¼ of an inch to 10, 20, or 30 square feet, as the case may be, in order to bring the *curve* within convenient dimensions—the number of feet in the respective areas or ordinates, ascertained by the rule, and through the points so given the curve is drawn as represented in the figure. This curve of areas, being a continuous and fair line, is a test of the correctness of the measurements, and an error in computation will be immediately detected. It will be observed that the curve meets the straight line at the stations 1 and 9. This must necessarily be the case ; for the first and last areas being at the extreme ends forward and aft, are equal to zero, and therefore there is nothing to set off from the straight line at those places. The measurements from which the several transverse areas are obtained being set off at each station at their proper distances asunder, the form of each cross section will be reproduced, and an error in measurement will be at once detected.

ESSENTIAL QUALITIES OF THE LAW.

Having thus, at length, given such illustrations and examples as appeared to be necessary to prove the correctness of the process, and show the mode of its application to those parts of vessels which require to be measured; there now only remains to describe some essential qualifications. These qualifications are summarily enumerated as follows :—

The evasion of Lawful Tonnage is prevented.

This is accomplished by the number and position of the precribed measurements ; these may be considered rather numerous for a practical operation ; but, on this point, it is to be borne in mind, that it has been found absolutely necessary to employ a multiplicity of measurements to insure the effectual prevention, by ingenious constructors, of so altering the forms of vessels between the measurements, as to evade thereby a just expression of the tonnage.

Inducement to construction of ill-formed Vessels removed.

This is effected by the prescribed measurements reaching every peculiarity of form which can be devised of the least importance as affecting the capacity ; whereas, under the operations of the rules hitherto established, it is only necessary, in consequence of the position and paucity of their measurements, to increase unduly those dimensions which are unaffected by the law, and an excess of capacity is attained without detriment to the register tonnage ; while, at the same time, the sailing and seaworthy qualities of the vessel may be thereby seriously compromised.

As, however, by the new mode, no such advantage, as capacity independent of register tonnage, is attainable, there will be no longer any inducement to give other forms to vessels than those tending best to develop the maximum advantage to be derived by a judicions blending of their sailing and carrying requirements.

Tonnage in proportion to capacity obtained.

A just and true relative expression of Register Tonnage in proportion to capacity is effected, whatever may be the nature of the materials used in the building, or whatever the form of the vessel may be :—This important desideratum is assured by the great degree of accuracy which the system affords in ascertaining the true capacities of vessels.

Wrong measurement can be detected.

Wrong measurement, whether by design or accident, can, at any time, be detected :—This is derived from the innate properties of the plan, and is accomplished by means of the formula used in the operation of measurement. By means of this formula detective curves can, at any time, be easily and quickly constructed; showing where any error, if any of material importance, has been introduced.

Cubic Feet in Hold ascertained.

We know, for instance, that in the register tonnage of a vessel computed by the new mode, every ton must consist exactly of 100 cubic feet; therefore, *to ascertain the number of cubic feet in a vessel's hold under the tonnage-deck*, it is only necessary to add two ciphers to the right of the figures expressing the register tons under that deck, and the number of cubic feet in the hold is at once shown:

For example, suppose the register tonnage under the tonnage-deck of a vessel to be 619 tons, then 61900 cubic feet is the cubical content of her hold.

Measurement of Cargo ascertained.

Again, *To find the Number of Tons of Export Measurement Goods of* 40 *cubic feet to the ton, which a vessel is enabled to take or stow*, it is only to divide the above number of cubic feet by 40, having first made the proper deduction due to the spaces which may be occupied by the crew, store-rooms, provisions and water, pump-well, beams, &c., &c.; which, on the whole, may, practically speaking, be estimated to amount to about twenty per cent.* or one-fifth of the whole cubic content under the tonnage-deck.

For example, the register tonnage under the tonnage-deck being as before 619 tons, the cubic content of the hold is 61900 cubic feet, and 61900 minus (61900 divided by 5) equal 49520 net cubic content, and 49520 divided by 40 equal 1238 tons, the quantity of export measurement goods that can be stowed. Or, in the case of import goods at 50 cubic feet to the ton, we have 49520 divided by 50 equal 990 tons.

Weight of Cargo ascertained.

And again, *If the Deadweight which a vessel can carry be required*, a useful approximation is obtained by dividing the number of cubic feet in the hold, as above, by 63; from which result must be taken the weights of the water, provisions, crew, and their

* Of which 20 per cent. $2\frac{1}{2}$ may be considered as due to the space occupied by the crew; $6\frac{1}{2}$ as due to twelve months' provisions and water in the usual proportion; 3 as due to beams, knees, shelf-pieces, pillars, keelson, &c., &c.; and 8 per cent. to petty officers' accommodation, storerooms, and dunnage. Mr. Henry Cleaver Chapman, an experienced ship-owner of Liverpool, considers that 25 per cent. may be deducted from the entire cubic content of the hold, as a fair allowance for these various items and impediments to stowage.

effects ; which, in the case of being provisioned for twelve months, may, practically speaking, be estimated to amount to about 7 per cent., or one-fourteenth of the above result :

For example, the register tonnage under the tonnage-deck being as before 619 tons, the cubic content of the hold is 61900 feet, and 61900 divided by 63 equal 982 tons, the gross weight of water, provisions, dunnage, and cargo, and 982 minus (982 divided by 14) equal 912 tons, the net weight of cargo and dunnage.

PROPORTIONS OF SHELLS OF SHIPS TO THEIR INTERNAL CAPACITIES.

Tables and Remarks connected with the thickness of the Sides or Shells of vessels built of different materials, as Oak, Fir and Iron.

TABLE No. 1.—Showing the Cubic Contents of the Hulls, to the height of the upper Deck, of Oak-built vessels, measured first to the outside of the Sides or Shell, and then to the inside (the difference showing the Cubic Contents of the Shells); showing, also, the Proportions which the Shells bear to their respective Internal Capacities ; these proportions being necessary data in the following remarks and subsequent investigations.

DESCRIPTION OF VESSEL.	Register Tonnage, New Mode.	Cubic contents of the hull to the height of the upper deck, measured to the outside, also to the inside, of the sides or shell.	Cubic contents of the sides or shell.	Proportion of the shell to the internal capacity.
	Tons.	Cubic feet.	Cubic ft.	Per cent.
East Indiaman with three decks. Old usual form.	1469.9	Out. 173482.61 to spar In. 146990.85 deck Diff. 26491.76	26491.7	18
East Indiaman with three decks. Unusually sharp.	1419.5	Out. 171586.46 to spar In. 141346.80 deck 30239.66	30239.66	21.4
East Indiaman with two decks. Rather sharp and shallow.	1057.2	Out. 115986 In. 95155.48 20830.52	20830.52	21.9
Coasting Brig. Usual form. Rather shallow.	98.6	12462 9703.96 2758.04	2758.04	28.4
Fruit Schooner. Very sharp and shallow.	109.8	13737 10554.4 3182.6	3182.6	30.1

MEDIUM THICKNESS OF THE SIDES OF VESSELS.

The following Table, showing, generally, the Proportion of the Oak Shells to the Internal Capacities in vessels of the usual form; also the medium Thicknesses of the Shells of Oak, Fir, and Iron-built vessels, is constructed, in its three first columns, upon the basis of the preceding Table, and in its two last columns upon Mr. Creuze's official Report, from the Office of Lloyd's Register of British and Foreign Shipping, to the Board of Trade:—

Table No. 2.

1 Tonnage New Mode.	2 Proportion of the oak shell to the internal capacity.	3 Medium thickness of the sides of oak vessels.	4 Medium thickness of the sides of fir vessels.	5 Medium thickness of the sides of iron vessels.
Tons. 1400	Per cent. 18	Inches. 22.26	Inches. ——	Inches. 7
1000	20.5	20.88	28.42	6.96
700	22.5	18.5	——	*
600	23.25	17.28	22.2	*
500	24	16.44	21.12	5.48
400	25	15.5	19.68	——
300	26	14.7	——	——
200	27	12.9	17.68	4
100	28	11.16	——	——

* And, generally speaking, the sides of iron vessels may be considered to be about one-third of the thickness of the sides of oak vessels of equal tonnage.

Remarks on the Results in the preceding Tables, Nos. 1 and 2.

Art. 1. In comparing the results in the foregoing Table, No. 1, it is seen, in the case of the two large Indiamen, that their tonnage, or true proportionate capacities, are the same within about fifty tons, while, at the same time, one of the vessels is of the usual full form, and the other unusually sharp. The capacities being so nearly the same, it is manifest that the sharp vessel must be greater in her principal dimensions to make up for her fineness in form; and we accordingly find, in comparing the dimensions, that she has an additional length of about twelve feet.

Reverting to the Table, it is observed, that in the full formed vessel the shell is eighteen per cent of the capacity, while in the other the proportion of shell to capacity is raised to twenty-one and a half per cent; showing, that in long sharp vessels of this class, the quantity of timber in the frame is greater than in fuller and shorter vessels of the same capacity or tonnage, by about three and a half per cent of the tonnage.

2. Again, comparing the Coasting Brig and Fruit Schooner, of 98 and 109 tons respectively, the former of the usual form, and the latter of the sharpest model, (the sharpness being balanced, as in the above case of the large vessels, by an addition of ten feet in length,) we see a difference of more than one and a-half per cent in the ratio of shell to capacity; proving, that in vessels of the smaller class, as well as in those of the larger, a greater quantity of timber is expended in the frame of long sharp vessels than in shorter and full-formed vessels of equal capacity.

3. Looking, generally, at the Table, No. 1, there appears, in regard to vessels of the usual form, to be a certain gradation, in the proportion of shell to capacity, through the various classes; the difference of that ratio between the largest and smallest vessel in the Table being about ten per cent.

Resulting from these considerations, the following facts appear to be established :—

More Timber in the frames of long sharp Vessels than in short full ones of equal tonnage.

(*a*). That long sharply formed vessels of the larger class require more timber in the construction of their frames, to the amount of one, two, or three-and-a-half per cent (according to their sharpness) of their internal capacity, than short full-formed vessels of the same tonnage or capacity (tonnage and capacity, by the new mode, being always in the same proportion); and in the smaller class of vessels, from one to one-and-a-half per cent.

In the usual form of Vessels, the larger the Vessel the less Timber in the frame in proportion to tonnage.

(*b*). And that, in vessels of the usual form, the larger the vessel the less timber, in proportion to capacity or tonnage, is required for the frame, by about three-quarters per cent (on an average) of the capacity, for every one hundred tons increase.

Timber in the frame of a Vessel approximately estimated.

4. With regard to Table, No. 2, a due consideration of the results in the 2nd column (which are a digest of the results, in reference to the usual form of vessels, in Table, No. 1) may,

occasionally, be found useful to the interests of the merchant shipbuilder. And holding them as general data, their utility (in conjunction with correct admeasurement) will be perceived from the consideration, that if the tonnage of a vessel, agreeably to the new mode, or any equally correct mode, be fixed upon, the quantity of converted timber required for the construction of her frame, can be pretty well estimated by their instrumentality.

Supposing, for instance, the tonnage, as above stated, to be given, it is only necessary to add two ciphers to the right of the integral figures, and we have the internal capacity in cubic feet; the respective per centage of which is then taken, as directed in column 2, which will give the approximate cubical content of the shell, or quantity of converted timber required for the construction of the frame; observing, at the same time, that if the model of the vessel be sharper (*a*) than the usual form, 1, 2, or even, in the case of large vessels, 3 per cent more of the capacity, according to the degree of sharpness, must be added to the above result, observing, however, that the small extra quantity above the upper deck will, in all cases, remain to be estimated and added hereto.

The following are Examples illustrative of the above proposition.

Example 1.—The tonnage of a vessel of the usual form, agreeably to the new mode, is 1469.9, say, 1470 tons. what is the approximate quantity of timber contained in her shell or frame?

1470 tons $\times$ 100 $=$ 147000 cubic feet, internal capacity.

Then (column 2) 18 per cent on 147000 cubic feet $=$ 26460 cubic feet, the approximate quantity of timber required; which is a result within 32 cubic feet of the shell of this vessel given in Table 1.

Example 2.—Suppose the tonnage of a vessel of the usual form, agreeably to the new mode, to be 1419 tons, what is the approximate quantity of timber in her frame?

1419 tons $\times$ 100 $=$ 141900 cubic feet, internal capacity.

Then (column 2) 18 per cent on 141900 cubic feet $=$ 25542 cubic feet, the approximate quantity of timber required, in the frame of a vessel of the usual form, of the above tonnage.

But supposing, on the other hand, the vessel to be of an unusually sharp construction, and of the same tonnage as above, then (*a*) an addition of $3\frac{1}{2}$ per cent of the capacity must be made to the above quantity; and as $3\frac{1}{2}$ per cent on 141900 cubic feet is 4966 cubic feet, we have

25542 cubic feet $+$ 4966 cubic feet $=$ 30508 cubic feet.

the approximate quantity of timber required, in the case of a very sharp vessel of this class. This result differs only about 268 cubic feet from the cubical content of the shell of this vessel, given in Table, No. 1.

Example 3.—The tonnage of a vessel of the usual form, by new mode, being 109 tons, what is the approximate quantity of timber in her shell or frame?

$$109 \text{ tons} \times 100 = 10900 \text{ cubic feet, internal capacity.}$$

Then (column 2) 28 per cent on 10900 cubic feet = 3052 cubic feet the approximate quantity of timber required in the frame of a vessel, of the usual form, of the above tonnage.

But supposing, on the other hand, the vessel to be of a very sharp model, a sharp Fruit Schooner, for instance, and of the same tonnage as above, then (*a*) an addition of $1\frac{1}{2}$ per cent of the capacity must be made to the above quantity; and as $1\frac{1}{2}$ per cent on 10900 cubic feet is 163.5 cubic feet, we have

$$3052 \text{ cubic feet} + 163.5 \text{ cubic feet} = 3215.5 \text{ cubic feet.}$$

the approximate quantity of timber required in the frame of a sharp vessel of this class; which is a result within 33 cubic feet of the shell of this vessel, given in Table, No. 1.

The utility of such practical estimates as the one here investigated, and as are found, also, described at pages 43 and 44, render further apparent the advantages of a correct system of admeasurement. No approximate system, framed mainly for the sake of brevity, and ease of computation, could afford sufficient correctness, or inspire the confidence necessary to render such collateral processes of any real practical advantage.

ADVANTAGE GIVEN, BY EXTERNAL MEASUREMENT, TO THIN-SIDED VESSELS.

Investigation, showing, in the case of Vessels of the same external form and dimensions, built severally of Oak, Fir, and Iron, what is the effect of the difference in the thickness of their sides or shell, on their internal capacities for Stowage; proving the advantage given by external measurement to thin-sided Vessels.

The three classes of vessels, of 1000, 500, and 200 tons, being considered sufficient for the purposes of the investigation, the following Table, having reference thereto, and which is derived from the columns of the preceding Table, No. 2, has, therefore, been extended only to those classes.

TABLE No. 3.

Class of Vessels.	1 Amount per cent of the Internal Capacity that is due to one inch of thickness of the Shell.	2 No. of Inches that the Shell of the Oak Vessel is thinner than that of the Fir Vessel.	3 No. of Inches that the Shell of the Iron Vessel is thinner than that of the Oak Vessel.	4 No. of Inches that the Shell of the Iron Vessel is thinner than that of the Fir Vessel.
Tons. 1000	Per Cent. 1 nearly.	Inches. 7.54	Inches. 14 nearly.	Inches. 21.46
500	1.46	4.68	10.96	15.64
200	2.09	4.78	8.9	13.68

Suppose three vessels, in each of the above classes, to be built, severally, of oak, fir, and iron, of the same *external* form and dimensions in every respect.

ART. 1 — *In the case of Vessels of* 1000 *Tons.*

1stly. Comparing the oak and fir vessels together: the oak vessel, being thinner in her shell than the fir vessel by 7.54 ins. (column 2), is larger in her internal capacity to that extent, and as one per cent is due to every inch of the thickness of the shell (column 1), the oak vessel exceeds the fir vessel in internal capacity by 1 per cent $\times$ 7.54 $=$ 7.54 per cent. Consequently, while under any system of *external* measurement, the register tonnage of these two vessels would be precisely the same, the oak vessel would have the advantage in capacity for stowage of cargo, to the amount of 7.54 per cent.

And 2ndly, Comparing the oak and iron vessels: the iron vessel being thinner in her shell than the oak vessel by fourteen inches (column 3), she is larger in her internal capacity to the extent of 1 per cent $\times$ 14 $=$ 14 per cent; and therefore, under external measurement, the iron vessel will have this advantage over the oak vessel.

And 3rdly. With regard to the fir and iron vessels: the iron vessel being thinner in her shell than the fir vessel by 21.46 inches, she is larger in her internal capacity to the extent of 1 per cent $\times$ 21.46 $=$ 21.46 per cent; and therefore, under external measurement, the iron vessel will have this advantage over the fir vessel.

2.—*In the case of Vessels of* 500 *Tons.*

1stly. Comparing the oak and fir vessels: as the former is thinner in her shell by 4.68 inches (column 2), and as 1.46 per cent of the internal capacity is, in this class, due to every inch of thickness (column 1), the oak vessel, therefore, exceeds the fir vessel in internal capacity by 1.46 per cent $\times$ 4.68 $=$ 6.8 per cent; and therefore has the advantage, to this extent, under external measurement.

And 2ndly. Comparing the oak and iron vessels: as the shell of the latter is thinner than that of the former by 10.96 inches, its internal capacity is greater by 1.46 per cent $\times$ 10.96 $=$ 16 per cent; and therefore the iron vessel has the advantage of the oak vessel to this extent.

And 3rdly. Comparing the fir and iron vessels: as the shell of the latter is thinner than that of the former by 15.64 inches, its internal capacity is greater by 1.46 per cent $\times$ 15.64 $=$ 22.8 per cent; and therefore the iron vessel has the advantage of the fir vessel to this extent.

3.—*In the case of Vessels of* 200 *Tons.*

1stly. Comparing the fir and oak vessels: the shell of the latter is 4.78 inches thinner than that of the former; and as in this class of vessels 2.09 per cent of the internal capacity is due to every inch of the thickness of the shell (column 1), therefore the internal capacity of the oak vessel is greater by 2.09 per cent $\times$ 4.78 $=$ 10 per cent; and therefore the oak vessel has the advantage of the fir vessel to this extent.

2ndly. Comparing the oak and iron vessels: the shell of the latter being thinner than that of the former by 8.9 inches, its internal capacity is greater by 2.09 per cent $\times$ 8.9 $=$ 18.6 per cent; and therefore the iron vessel has the advantage of the oak vessel to this extent.

3rdly. Comparing the fir and iron vessels: the shell of the latter being thinner than that of the former by 13.68 inches, its internal capacity is greater by 2.09 per cent $\times$ 13.68 $=$ 28.6 per cent; and therefore the iron vessel, under external measurement, has the advantage of the fir vessel to this amount.

Synopsis of the advantages which thin-sided vessels have over thick-sided vessels.

4. Synopsis of the preceding investigation, showing, in a tabular form, the advantage in reference to capacity for stowage (under any system of external measurement) which oak-built vessels have over those built of fir, also the advantage which iron-built vessels have over both.

TABLE No. 4.

Class of Vessels.	Advantage of Oak over Fir Vessels.	Advantage of Iron over Oak Vessels.	Advantage of Iron over Fir Vessels.
Tons. 1000	Per Cent. 7.54	Per Cent. 14	Per Cent. 21.46
500	6.8	16	22.8
200	10	18.6	28.6

WEIGHTS OF THE HULLS OF IRON AND WOOD-BUILT VESSELS.

The Weights of the Hulls of Iron and Wood (Oak) built Vessels compared, showing the effects of their difference of buoyancy in the increased weight of cargo which Iron Vessels are enabled to carry.

From the difficulty, it may almost be said from the impossibility, of procuring the requisite data for directly comparing the buoyancy of iron and wood vessels (such data consisting of the exact weights of sister ships of different sizes, built of each kind of material, alike respectively in every other respect), it has, for this reason, been found necessary to have recourse to the more indirect means of inductive calculations.

The data at hand, being from a responsible official source, and therefore to be depended upon for correctness, consist of the weights of the wood and iron hulls of various war steamers, from the largest to the smallest size, and of their tonnage under the old measurement, or builder's tonnage, as it is frequently termed.

The method of obtaining from these data the comparative buoyancy of the two kinds of vessels is as follows:

The vessels from which these calculations have been obtained, being wholly vessels of war, may be considered of similar form, and therefore the internal and external capacities are, practically speaking, in proportion to their length, breadth and depth jointly; consequently their differences, namely, the hulls or weights of the hulls, (considering the hulls to be homogeneous,) are in the same proportion. But the old tonnage is in proportion to the length, breadth and depth jointly (considering the depth to be in proportion to the half breadth), consequently the weights of the hulls are in proportion to the old tonnage.

Therefore it is only necessary to find, from the table annexed, the mean tonnage of each of the two kinds of vessels, also the mean weights of their hulls respectively; and their comparative buoyancy is thence readily ascertained by means of simple proportions.

The Light Displacements or Weights of the Hulls of several War Steam Vessels, shown under their respective heads of Iron-built and Wood-built Vessels; also the old or Builders' Tonnage of the same, in reference to ascertaining the comparative buoyancy of Iron-built and Wood-built Vessels.

TABLE No. 5.

Iron-built Vessels.			Wood-built Vessels.		
Ships' Names.	Weight of Hulls.	Old Rég. Tonnage.	Ships' Names.	Weight of Hulls.	Old Reg. Tonnage.
	Tons.	Reg. T's.		Tons.	Reg. Tons.
Simoon . .	1350	1980	Arrogant .	1190	1872
Vulcan . .	1000	1764	Terrible . .	1420	1847
Greenock .	955	1413	Retribution .	1275	1641
Birkenhead .	917	1405	Dauntless .	1010	1497
Megara . .	753	1397	Amphion .	977	1474
Trident . .	385	850	Avenger . .	1160	1444
Triton . .	394	654	Odin . . .	1070	1310
Antelope .	390	650	Magicienne .	973	1255
Oberon . .	383	649	Conflict . .	740	1058
Grappler .	294	557	Buzzard .	749	997
Sharpshooter	204	503	Archer . .	602	970
Jackall . .	180	340	Phœnix . .	660	809
			Acheron . .	337	722
	12)7205	12)12162	Volcano . .	407	720
			Reynard . .	330	516
	600.42 Mean weight.	1013.5 Mean Register Tonnage.	Rifleman .	256	486
				16)13156	16)18618
				822.25 Mean Weight.	1163.62 Mean Reg. Tonnage.

From the above results we derive the following proportions :—

Reg. Ton. : Weight of Iron Hull = 1013.5 : 600.42 = 1 : .5924
Reg. Ton. : Weight of Wood Hull = 1163.62 : 822.25 = 1 : .7066

Hence it is manifest that

Weight of Iron Hull : Weight of Wood Hull = .5924 : .7066

Or algebraically, thus :—

Weight of Iron Hull : Reg. Ton. = .5924 : 1
Reg. Ton. : Weight of Wo. Hull = 1 : .7066

Striking out the antecedent and consequent æquales

Weight of Iron Hull : Weight of Wood Hull = .5924 : .7066

In Steam Vessels Iron Hull more buoyant than Wood Hull.

That is, while the weight of the iron hull is expressed by the quantity .5924, the weight of the wood hull is relatively expressed by the quantity .7066; and therefore the difference between the two, namely, .1142, is the relative quantity by which the iron hull is lighter or more buoyant than the hull built of wood. But .1142 is 16.16 per cent on .7066, the weight of the wood hull; therefore—

In the case of *steam* vessels, the vessel built of *iron* is more buoyant than the vessel built of *wood*, by about 16 per cent of the weight of the wood hull.

The above result, being founded on data derived solely from steam vessels, the wood hulls of which are of less scantling than the hulls of sailing vessels, it is consequently only applicable to steam vessels. A correction, however, in this respect is easily made in it, by which the comparative buoyancy of the two kinds of hulls, in regard to sailing vessels, is equally ascertained. This is as follows:—

Difference in Scantling allowed in Steam-vessels.

With regard to vessels built of iron, the thickness of the frame or shell is the same, whether they be propelled by the power of steam or sails; but this is not the case in respect of vessels built of wood. By the regulations of the "Society of Lloyd's Register of British and Foreign Shipping," steam vessels under 300 tons may have the scantlings of a sailing vessel of one-third less tonnage, and those above 300 tons the scantlings of a sailing vessel of one-fourth less tonnage. Therefore this difference in scantling allowed in steam vessels, amounting generally, both in government and merchant vessels, to about one inch in twelve inches of the scantling of sailing vessels, or 8.333 per cent, must be added to the weight of the wood hulls employed in the above calculation, in order to bring them to the weights of the hulls of sailing vessels. Or, in other words, the iron hull, with regard to sailing vessels, has this additional buoyancy; and as 16.16 per cent of the weight of the wood hulls of steamers is only 14.9 per cent on the weight of the wood hulls of sailing vessels, therefore—

In sailing-vessels Iron Hull still more buoyant than in steam vessels.

In the case of *sailing* vessels, the iron hull is more buoyant than the wood hull by about $14.9 + 8.333$ per cent $= 23.2$, or about 23 per cent of the weight of the wood hull.

From these results are deduced the following practical conclusions:

1. With regard to *sailing* vessels.—It is known from experience that in merchant vessels the weight of the wood hull, generally speaking, is about one-third of the whole displacement of the vessel, and that the weight of the cargo is about three-fifths of that displacement; therefore the weight of the hull is to the weight of the cargo as 1-3 to 3-5, or as 5 to 9: or, in other words, the weight of the hull is about 5-9 the weight of the cargo. Therefore, the superior buoyancy of the iron vessel being, as before shown, about 23 per cent of the weight of the wood hull, is five-ninths of 23 per cent, or about 13 per cent of the weight of the cargo.

Hence, if two *sailing* vessels be built from the same drawing, one of wood and the other of iron, the iron vessel will, if both vessels be loaded to the same draught of water, carry a greater weight of cargo than the wood vessel by about 13 per cent, which, in a vessel of the usual form of about 700 tons old measurement, will amount to about 135 tons deadweight; and which, if not shipped by the iron vessel, will give her the advantage of drawing about sixteen inches less water than the wood vessel.

2. With regard to *steam* vessels.—The wood hull being, as before stated, of less scantling than in sailing vessels, its weight will be less in proportion to the cargo than in sailing vessels; whilst on the other hand this may be considered as quite neutralized in consequence of the extreme sharpness of form in steam-vessels, by which more timber is expended in the frame in proportion to capacity; consequently the weight of the wood hull in steam-vessels may, as in sailing vessels, be considered to be equal to about five-ninths of the weight of the cargo. Therefore the superior buoyancy of the iron steam-vessel, as before shown, being about 16 per cent of the weight of the wood hull, is five-ninths of 16 per cent, or nearly 9 per cent of the weight of the cargo.

Hence, if two *steam* vessels be built from the same drawing, one of wood and the other of iron, the iron vessel will, if both vessels be loaded to the same draught of water, carry a greater weight of cargo than the wood vessel by about 9 per cent, which, in a vessel of 700 tons old measurement, and of the usual steam vessel form, will amount to about 70 tons deadweight; and which, if not shipped by the iron vessel, will give her the advantage of drawing about nine inches less water than the wood vessel.

The advantage of iron-built vessels with regard to the power of carrying heavy cargoes, as well as to capacity for the stowage of light merchandise is therefore indisputable.

FORMULA TO APPROXIMATE REGISTER TONNAGE UNDER ANY PROPOSED DIMENSIONS.

[Extracts from Mr Moorsom's Report, published in the proceedings of the "Institute of Naval Architecture."—London, 1860.]

To Shipbuilders who may wish to know, before the construction of an intended design, the approximate register tonnage under any proposed principal dimensions, the following *formula* (which has received the approbation of Messrs. Martin and Ritchie, the two chief surveyors of Lloyd's, who, from their great experience and intelligence, are authorities on the subject) will be found useful, as it gives the tonnage, on an average, generally speaking, within about 2½ per cent.

Let L represent the inside length on upper deck from plank at bow to plank at stern.

" B represent the inside main breadth from ceiling to ceiling.

" D represent the inside midship depth from upper deck to ceiling at limber-strake.

Then the register tonnage of any ship will be equal to $\frac{L \times B \times D}{100}$, multiplied by the decimal factor opposite the class in the following Table to which she belongs:

Sailing Ships.	Cotton and Sugar Ships, old full form....	·8
	Ships of the present usual form..........	·7
Steam Vessels and Clippers.	Ships of two Decks....................	·65
	Ships of three Decks..................	·68
Yachts.	Vessels above 60 Tons	·5
	Vessels, small	·45

RULE TO ASCERTAIN THE MEASUREMENTS AND DEADWEIGT CARGO OF SHIPS.

A brief Explanation of the Nature of the Register Tonnage of a Ship as ascertained under the "Merchant's Shipping Act, 1854"; and of the easy means it affords for estimating, approximately, the Measurements and Deadweight Cargo of Ships.

1*st.* The Register Tonnage of a Ship expresses her entire internal cubical capacity in tons of 100 cubic feet each; so that it is only necessary to multiply such tonnage by 100, and the entire internal capacity of the ship in cubic feet is immediately shown; and from which an owner can, by making such deductions for passengers, provisions, stores, &c., as the circumstances of the particular voyage may require, arrive at the net space in cubic feet for the purpose of cargo.

2nd. To ascertain approximately for an average length of voyage the Measurement Cargo at 40 feet to the ton which a ship can carry, (as many owners may be unwilling to trouble themselves with the above-mentioned deduction,) it is only necessary to multiply the number of register tons contained under her tonnage-deck, as shown separately in the Certificate of Registry, by the factor $1\frac{7}{8}$ and the product will be the approximate measurement cargo required.

3d. To ascertain approximately the Deadweight Cargo in tons which a ship can safely carry on an average length of voyage, (deadweight bearing a certain qualified relation to internal capacity,) it is only necessary to multiply the number of register tons under her tonnage-deck by the factor $1\frac{1}{2}$, and the product will be the approximate deadweight cargo required.

4th. With regard to the cargoes of Coasters and Colliers ascertained as above, whose short voyages require but a small equipment of provisions and stores, and whose frames or shells are of larger scantling in proportion to their capacity than in the larger classes of vessels, about 10 per cent may be added to the said results; while, on the contrary, about 10 per cent may be deducted in the case of the larger vessels going longer voyages.

5th. In the case of the Measurement Cargoes of Steam Vessels, the spaces occupied by the machinery, fuel and passengers, and cabin under deck, must be deducted from the space or tonnage under the deck, before the application of the measurement factor thereto; and in the case of their deadweight cargoes, the weight of the machinery, water in the boilers, and fuel, must be deducted from the whole deadweight as ascertained above by the application of the deadweight factor.

It may also be as well to observe, in regard to this latter question of weight-cargoes, that parties are agitating as to the desirableness of placing a scale of tonnage on a ship's Certificate of Registry, to show the weight of cargo carried at different lines of flotation, for the convenience of ship-owners, brokers and masters. I question, however, if the utility of this object is at all commensurate with the labor and difficulty to be met with in its attainment; for I have yet to learn that even the parties themselves for whose interest it is proposed, desire such a document. Moreover, as the information to be derived from it is entirely for the private purposes of the ship-owner and his agents, and can be furnished him by any respectable builder or surveyor of shipping, it ought to be so procured (if such information be necessary), and most certainly not at the public expense; an expense of no inconsiderable amount, if the document had to be furnished to the whole commercial navy; for upon a moderate calculation, the number of ships of the United Kingdom being about 27,000, it would occupy ten or twelve practised draughtsmen, nine or ten years for its completion, and probably two or three others, in addition, for the ships annually building. Again, a ship's certificate of registry, on which it is proposed to place the scale in question, is simply a document of nationality, fiscal tonnage, and identity, and should not, in my opinion, be incumbered with other matter not strictly relevant thereto. All that appears to be requisite for the convenience of an owner, as regards particular point of weight, is, that he should know the number of tons necessary to be shipped to depress or sink his ship to the extent of one inch in the neighbourhood of the load-water-line; for the weight of one inch immersion varies but little, practically speaking, within the range of the load and light draughts of merchantmen; and with this simple information he can be supplied by almost any respectable shipbuilder or surveyor at any port of the kingdom. The nature of this information, and the extent of its practical conveniences, are shown by the following Table:

Sailing Vessels.	Gross Register Tonnage under Deck.	Tons Weight due to 1 Inch Immersion in the neighbourhood of Load Line	Tons Weight to 1 Inch in neighbourhood of Light Line.
Duncan Dunbar	1200	16.56	14.56
Holmsdale . .	1100	15.50	13.95
Suffolk . . .	850	13.00	11.59
Dorothy . .	700	11.64	10.29
Harwood . .	400	7.42	6.58
Fidelity . . .	71	2.44	2.14
Steam Vessels.			
Great Eastern.	18915	95.00	87.00
Persia . . .	3100	30.00	26.60
Australasian .	2500	24.35	21.00
Mauritius . .	1500	18.50	16.29
Christina . .	700	11.58	10.93
Grange . . .	400	8.40	7.82
Thor	300	7.55	6.99
		261.94 235.74	235.74
		26.20 difference or 10 per cent on the average.	

It is seen from the above Table that the weight due to *one* inch immersion at the two different draughts of load and light lines vary on an average on several vessels to the extent only of about *ten* per cent; and, therefore, that the weight which would sink a vessel *one* inch when she is floating at her load line, would sink her *one-tenth* of an inch more when floating at her light line. It is hence manifest, that if we take this weight as that which would sink a vessel *one* inch at any point between the light and load draughts, it would involve a mean error of only *one-twentieth* of an inch to *one* inch, or at the rate of a little more than *half* of an inch to a foot,—an approximation sufficiently near for all commercial purposes (should such information be required) connected with the loading and unloading of ships.

CENTRE OF GRAVITY OF DISPLACEMENT.

Method of ascertaining the Centre of Gravity of the Displacement of a Vessel, founded upon the same general Process as the Rule for determining the Register Tonnage.

Preliminary Observations.

Remarks on the position of the Centre of Gravity of Displacement.

The centre of gravity of displacement is a most important element in the science of naval construction. On its being properly situated, both as regards its longitudinal and vertical position, depends the acquisition of many of the most important sea-boat properties of vessels. The celebrated Chapman, the most eminently practical and scientific author in Naval Architecture with whom we are acquainted, says, that in submitting vessels of first-rate character for their velocities and easiness of motions at sea to scientific investigation, he invariably found the centre of gravity of displacement to be situated within the limits of the 1-100th and 1-50th of the length of the plane of flotation before its middle point.

A practical remark of this nature deduced from scientific analysis, in connection with practical observations, from such an authority as Chapman, must be of considerable value, and worthy the attention of all naval architects.

On the position of this centre of buoyancy depends, also, the position of the common centre of gravity of the ship, or that important point around which all the rotatory and oscillatory movements of the vessel take place ; for, by a well known law of hydrostatics, a body floating on a fluid will not be at rest till its centre of gravity and that of the displacement, or buoyancy, are in the same vertical line. Consequently, if the position of the centre of gravity of displacement, under a determined line of flotation, be not in the same vertical line with the common centre of gravity of the ship, she will necessarily revolve round the latter till it be so, altering more or less, as the case may be, the intended line of flotation; and which can only be preserved by some different arrangement of the cargo or equipment, or by the addition of, otherwise unnecessary, ballast.

It being, therefore, desirable on all occasions of the construction of new vessels, to know whether the centre of buoyancy be properly situated, the following easy and practically correct method for ascertaining it (founded on the principles of the general process of the Rule for the admeasurement of tonnage) will, perhaps, be acceptable to those who may wish to attend to this important element in the designing of their vessels.

It may be desirable first to explain the general theorem for ascertaining the common centre of gravity of any system of bodies, which is as follows :—

Fig. 1.

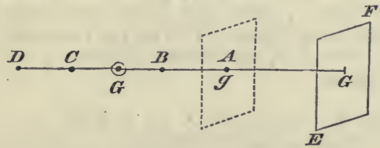
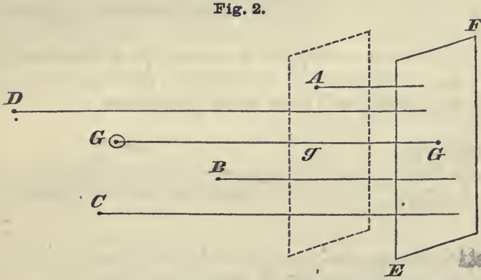


Fig. 2.



ART. 1.—It is known (from mechanics) that if A, B, C, D, &c., figs. 1 and 2, be the weights of a number of bodies situated as regards their respective centres of gravity, at the perpendicular distances a, b, c, d, &c., from any plane EF given in position; then the perpendicular distance of their common centre of gravity G (⊙) from the plane, is equal to the sum of all the moments from the plane divided by the sum of all the weights; that is,

$$G\,G = \frac{A\times a + B\times b + C\times c + D\times d + \&c.}{A + B + C + D + \&c} = \frac{A\times a + B\times b + C\times c + D\times d + \&c.}{\text{whole weight.}}$$

And as in homogeneous bodies the cubical contents are in proportion to the weights, the equation is equally true when A, B, C, &c., represent the cubical contents of such bodies; therefore

$$G\,G = \frac{A\times a + B\times b + C\times c + D\times d + \&c.}{\text{whole cubic contents.}}$$

ART 2.—In the application of the above theorem to the displacement of a ship, we must consider A, B, C, &c., as representing consecutively the whole of the equi-distant transverse areas, or infinitesimal laminæ, the integration of which make up the whole displacement. And if we suppose the common interval between A, B, C, &c., or the areas, to be represented by m, and the plane $E\,F$ to be situated at A, or area No. 1, as shown in the Figs. by the dotted planes, then the perpendicular distance $a = 0$, the perpendicular distance $b = m$, the perpendicular distance $c = 2\,m$, and $d = 3\,m$, and so on. Hence by substitution the equation becomes

$$G\,g = \frac{A \times 0 + B \times 1m + C \times 2m + D \times 3m + \&c.}{\text{cubic contents of displacement.}} = \frac{(A \times 0 + B \times 1 + C \times 2 + D \times 3 + \&c.) \times m}{\text{cubic contents of displacement.}}$$

And if the areas multiplied respectively, as here shown, by 0, 1, 2, 3, &c., be termed the functions of the areas, the equation, verbally expressed, will then be as follows:—

$$\left.\begin{array}{l}\text{The distance of the}\\ \text{centre of gravity of}\\ \text{displacement from}\\ \text{area No. 1, meas-}\\ \text{ured on the load}\\ \text{water-line.}\end{array}\right\} = \frac{\text{sum of all the functions of the areas} \times \text{common interval.}}{\text{cubical contents of displacement.}}$$

Now, the integration, or sum of all the functions of the areas, is to be arrived at precisely in the same manner as the summing of the areas in the Rule for the admeasurement of the internal capacity; that is, (numbering them successively from forward 1, 2, 3, &c.,) multiply all the even numbered *functions* by 4, and all the odd numbered ones by 2, except the first and last, and to the sum of these products add the first and last *functions*, and multiply this whole sum by one-third of the common interval between the areas, which gives the sum of all the functions required; which, as the above equation shows, is to be multiplied by the common interval, and then divided by the cubic contents of the displacement, to give the position of the centre of gravity.

Hence the last equation for finding the centre of gravity of displacement in its extended form, becomes

$$\left.\begin{array}{l}\text{The distance of cen-}\\ \text{tre of gravity of dis-}\\ \text{placement from area}\\ \text{No. 1, measured on}\\ \text{load-water line.}\end{array}\right\} = \frac{\begin{array}{l}\text{(Sum of even No. functs.} \times 4 + \text{sum of odd No. functs.}\\ \times 2\text{, except first and last} + \text{sum of first and last functs.)}\\ \times \tfrac{1}{3}\text{ common interval} \times \text{common interval.}\end{array}}{\text{cubical content of displacement.}}$$

from which the following general formula, for convenience of computation, is derived.

* *General Formula for finding the Centre of Gravity of Displacement, supposing the Areas of the Sections to be already found.*

Length on load-water line from rabbet of stem to rabbet of stern-post ÷ = ft. common interval between areas.

No. of Areas.	Areas. Sq. Ft.		Functions of Areas.	Multipliers.	Products.
1		×0		1	
2		×1		4	
3		×2		2	
4		×3		4	
5		×4		1	

is ⅓ of com. int. betn. areas.

sum of all the functs. of areas.
is common int. between areas.

sum of moments from plane, or area 1.

and $\frac{\text{sum of moments}}{\text{displacement.}}$ = distance of centre of grav. from area 1.

* In this formula five areas are shown to be employed; but in the case of employing a less or greater number (always, however, odd), the formula will be necessarily varied, agreeably to the number of areas or ordinates, as shown in the Examples of the Rule for the admeasurement of tonnage.

Position of the Centre of Gravity of Displacement below load-water line.

The process, as has been illustrated, for ascertaining the position of the centre of gravity of displacement in a longitudinal sense, is equally applicable to finding it in a vertical sense, that is, its distance below the plane of flotation.

In this case, the horizontal, instead of the vertical areas, are to be employed: they are to be numbered in succession from above; the plane in position from which the moments are to be calculated, being considered to be in the plane of flotation or area No. 1.

LOAD DISPLACEMENT OF A VESSEL.

Method of finding the Load Displacement of a Vessel, by means of the Formula for the Admeasurement of Tonnage.

The load displacement, one of the most important elements in the construction of a vessel of war, being equal in weight to the entire weight of the vessel, comprising the weights of the hull, masts and yards and their furniture, armament, and entire equipment, is at all times determined with the greatest nicety.

The load displacement being equal to the entire weight of the vessel, is that volume of water which is displaced by the body of the vessel when completely ready for sea ; and is, consequently, bounded by the load-water line : it is, therefore, manifest that we have only to ascertain the exact cubical content of the vessel, *to the outside form*, which lies under the load-water line, and we have the true load displacement.

The length of this portion of the body is, therefore, the length on the load-water line, measured from the outside of the plank at the stem, to the outside of the plank at the stern-post; and, therefore, in the application of the plan to the finding of the cubical content of the displacement, it is this length which is to be divided into the required number of equal parts instead of the internal length at the deck, as prescribed in the Rule for determining the register tonnage.

The transverse areas of the displacement being sections of the external volume, the depth at each area is taken from the load-water line to the outside of the plank or rabbet at the keel, instead of the internal depths as prescribed in the Rule for the admeasurement of register tonnage.

In all other respects the process is identical with that of the Rule, except that the cubical content is to be divided by 35, (there being 35 cubic feet of water to a ton weight,) in order to give the *weight* of the displacement in tons, instead of being divided by 100, as therein prescribed, for the register tonnage.

Although it may not be so necessary in the designing of merchant ships, as it is with vessels of war, to ascertain the exact weight of the displacement to a determined draught of water, yet there are occasions when an easy and correct method for this purpose might be of great utility and convenience ; and this could only be effected by means of calculations on the displacement, allowing the necessary displacement for the whole weight of the vessel completely equipped, in addition to the weight she might be required to carry.

CUBATURE OF BODIES OF WHATEVER CONFIGURATION.

The general formula for the admeasurement of the capacity of vessels, is equally applicable to the cubature of all bodies of whatever configuration. It measures the capacity of the vessel herself not more correctly than it will measure the number of cubic feet contained in one of the angular chocks under her beams, or in one of the variously curved timbers of which her frame is composed. Giving thus the true mensuration of all bodies under all circumstances, it is obvious no evasive measurement can result from it.

It will be seen from the examples given, that it ascertains the cubature of the *common wedge*, of the *parallelopiped*, of the *pyramid*, of the *cone*, and of the *frustums* of these bodies, &c., &c., however insignificant or colossal their dimensions, with the same geometrical exactness; and, thus, may be said to form, in itself, a complete theory of practical mensuration for bodies of all shapes and proportions.

Cubature of the Pyramid.

Application of the General Process to the Cubature, and to the finding of the Centre of Gravity of Bodies unconnected with Naval Architecture.

To find the cubical contents by the general process, three breadths are measured; namely one at top, one in the middle, and one at the base.

Top	No. 1.	breadth 0 ft.	Area 0 sq. ft.
Middle	No. 2.	breadth 2 ft.	Area 4 sq. ft.
Base	No. 3.	breadth 4 ft.	Area 16 sq. ft.

Note.—A work "on Tonnage," might naturally be considered as investigating only such matters as have reference to this particular question; and, therefore, as other matter which may be deemed of an irrelevant character has been superadded, some reason assigned for such digression from the special object of the work would seem to be called for.

It may, therefore, be stated, that this supererogatory matter is introduced to show the general applicability of the new process to all professional investigations connected with the theory of Naval Architecture; and thus to prove that its utility is not to be considered as applicable solely to the purposes of tonnage.

We would therefore submit, particularly to the members of the profession, the advantages to be derived from so correct and general a theory; and by which, the merchant Shipbuilder, in the ordinary practice of measuring his ships, will necessarily become familiar (if he is not already so) with a process affording a most correct and easy method for all the theoretic inquiries above alluded to, should he wish to render these advantages available in the pursuit of improvement in the forms and proportions of his models.

Let a vertical section be represented as passing through the axis of a square pyramid, the perpendicular height of which is twelve feet, and breadth of base four feet.

Let the perpendicular height be divided into two equal parts. Then the breadth of the base, being equal to four feet, the middle will be found, either by measurement or similar triangles, to be equal to two feet. And the areas at the apex, middle point and base, being as before stated, the cubature is as follows:—

General Formula for Cubature.

Three Transverse Areas being given.

Length from Apex to Base, 12 ft. ÷ 2 = 6 ft., the common interval between areas.			
No. of Areas.	Multipliers.	Areas Sq. Ft.	Products.
1	1	0	0
2	4	4	16
3	1	16	16

32
2 is ⅓ of 6 feet, com. interval betn. areas.

64 cubic content of pyramid.

Now, it is known (from fluxions) that the cubature of the pyramid is equal to the area of the base multiplied by one-third of the perpendicular height; that is,

$$16 \times (12 \div 3) = 64 \text{ cubic content, geometrically.}$$

Hence it is seen that the above cubature is mathematically correct. It will be perceived that in the above formula one term of the general formula of the Rule for the admeasurement of tonnage is wanting—namely the odd numbered ordinates multiplied by 2. The reason of this is, that in the case of the employment of only three ordinates there are no odd numbered ordinates beyond the first and last.

If five areas are employed instead of three, the result will be precisely the same, but the process will be of course so much the longer.

To find the Position of the Centre of Gravity of the Pyramid.

General Formula for Finding the Distance of the Centre of Gravity from Area No. 1.

Three Transverse Areas being given.

Length or Perpendicular Height of Pyramid, = 12 ft. ÷ 2 = 6 ft., com. int. betn. areas.					
No. of Areas.	Areas. Sq. Ft.		Functions of Areas.	Multipliers.	Products.
{apex 1	0	× 0	0	1	0
2	4	× 1	4	4	16
3	16	× 2	32	1	32

Now it is known (from fluxions) that in the pyramid the distance of the centre of gravity from the apex is equal to three-quarters of its perpendicular height; that is,

¾ of 12 ft. = 9 ft. is the distance of the centre of gravity of pyramid from apex, geometrically.

48
2 is ½ of 6 ft. com. int. betn. areas.

96 sum of functions of areas.
6 is com. int. betn. areas.

576 sum of moments from Area No. 1, or apex.

Then, as the distance of the centre of gravity from Area 1 is equal to the sum of the moments divided by the cubical content, and the cubical content is 64 feet (see page 62), we have,

576 ÷ 64 = 9 ft. the distance of cent. of grav. from Area 1, or apex.

Hence it is seen that the above process for finding the centre of gravity of a body, founded on the general process is, in its application to the pyramid, geometrically correct.

The General Process applied to the Measurement of a piece of Timber.

The process will be found to be equally applicable to the practical cubature of all other bodies as to that, shown in the preceding example, of the pyramid.

Suppose, for instance, the measurement of a piece of timber, having plane sides contained between any two parallel rectangular ends, were required.

Supposing the dimensions at the ends to be 3 by 4 feet, and 5 by 6 feet, and the length 30 feet.

Measurement by General Process.

The nature of the process always requiring an *odd* number of equidistant ordinates, an additional area to those at the ends must consequently be taken in the middle between them. Measure, therefore, a breadth and thickness at the middle of the piece, which will be found to be five feet and four feet respectively, and therefore the area at the middle point will be equal to 20 square feet. And the areas at the ends being as respectively shown in the formula, the cubature is as follows:

General Formula.

Length 30 ft. ÷ 2 = 15 ft. the com. int. betn. areas.

No. of Areas.	Multipliers.	Areas. Sq. Ft.	Products.
1	1	12	12
2	4	20	80
3	1	30	30

122
5 is ⅓ of 15 ft., com. int. betn. areas.

610 cubic feet.

Measurement Geometrically is,

Cubical content (by a known geometrical rule) $= (6\times5+4\times3+(6+4)\times(5+3)) \times$ 1-6 of 30 ft. length $= (30+12+10\times8) \times 5 = 610$ cubic feet.

Hence it is proved that a log of timber of this form is measured by the general process with geometrical truth.

If the timber were of a circular form, as part of a mast or yard, the cubical content would be ascertained with equal practical truthfulness: and so, likewise, of any other form, provided the areas be first correctly determined.

If the log should consist of irregular portions,—that is, if it should increase or diminish abruptly in its bulk or dimensions in one or more places (as is often the case in rough timber),—each such portion should be submitted separately to the process, and the several results added together for the whole content.